

A COMPARATIVE ANALYSIS OF REFORMS IN ORGANIZING CURRICULA
AND METHODS OF SECONDARY SCIENCE INSTRUCTION IN THE UNITED
STATES DURING THE LAST DECADES OF THE NINETEENTH AND
TWENTIETH CENTURIES

by

Pamela C. Turpin

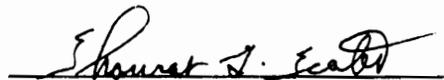
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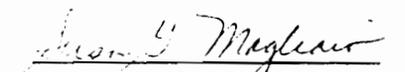
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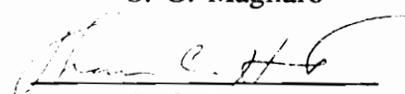
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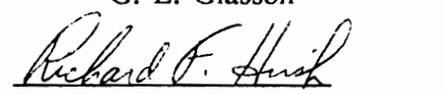
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(ABSTRACT)

This study involved a comparative analysis of reforms in the organization and structure of curricula and instruction in science education in the United States during the last decades of the nineteenth and twentieth centuries. A review of literature of these periods revealed similar concerns and goals for science instructional reform in schools.

With the use of primary and secondary sources from these decades, a comparison of the conditions surrounding the reform movements was made. The author explored such concerns as educational norms, aims, values, customs, curricula content, instructional methods, psychological bases and their relationships with the technological and scientific cultures of the times. This comparison characterized common factors associated with the two reform movements.

A historical characterization of the two reform periods identified relationships and responses of science education reform to social, educational, scientific, technological, and economic influences. These relationships and responses represent some of the common factors that late-nineteenth century and late-twentieth century reform movements in

science education share. The author determined that although the terms, phrases, and jargon used by late-nineteenth century science education reformers sound similar to those used today, the reform efforts are not as similar as they seem.

Different meanings of reform terminology used by educators of the two time periods resulted in science education means and goals that are distinct for each period, although the terminology used to describe these ideals sounds and appears very similar. This study shows how science education reforms in the late-nineteenth and late-twentieth centuries responded to the world of which they were a part, and how under apparent similar conditions, responses of reformers appear similar, but in reality are different.

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CHAPTER 1

STATUS AND REFORM: AN INTRODUCTION

The essential method is that we allow nothing to come between the student and the object which he studies. The book or the chart or lecture which can be used in place of the real thing is the thing you should never use. Your students should see for themselves, and draw their own conclusions from what they see....Stick to your frog, if you are studying frogs, and he will teach you more of the science of animals than can be learned from all the memorized classifications that you can bracket out on a hundred rods of blackboard!...The book is placed in their [the teachers] hands by the school board, and they teach by the book. If the book comes to them wrong side up, their teaching is forever inverted....This is the vital fault of much of our teaching of elementary science. It is not real; it is not the study of nature, only dust-heaps of old definitions....It is better to have a few forms well studied than to teach a little about many hundred species.

A description of science reform ideas and concerns from 1993? These excerpted quotations seem to advocate hands-on instruction, active student participation, relevance, proceeding from the known and a *less is more* approach to science instruction -- instructional procedures supported by today's science education reform efforts. They also point out problems of rote memorization of terms and the authoritarian use of textbooks by teachers, two of the most often cited problems associated with science instruction in

the 1990s. From which of the following reform movements do these quotations come? Scope, Sequence and Coordination* (SS&C), Project 2061,** or Science and Technology and Society (STS)*** studies?

Actually, these observations and suggestions come from an article, "Science in the High School" written by D.S. Jordan and published in *Popular Science Monthly* in 1890. Jordan, a zoologist by training, and at that time President of the University of Indiana, presented this paper to the Indiana State Teachers' Association, December 26, 1889. With a few changes in the late-nineteenth century wording, a gathering of late-twentieth century science teachers and reformers would agree with most of the ideas presented in this article. For 1993 science educators, these ideas sound familiar and appear similar to what they hear from contemporary reform movements. Jordan appeared to have foresight into the 1990s' reform efforts of science education. His ideas were very characteristic of ideas of other science educators of his time.

A review of literature on science education in the United States from the 1880s and 1890s reveals goals, aims, and concerns about instructional methods that are similar to those in the 1980s and 1990s. Many concerns about what a student should be able to do after completion of the study of science appear to remain the same for both time periods, although underlying learning theories, practices of educational psychology and reflections about the nature of scientific knowledge have changed in the last one hundred years. A comparison of the times and their concerns, concepts of the nature of science, the educational value of science instruction and the pedagogical attainment of these values and

* Scope, Sequence, and Coordination is the reform effort advocated by the National Science Teachers' Association.

** Project 2061 is the reform movement designed by the American Association for the Advancement of Science.

*** Science/Technology/Society is a reform movement supported independently by many science educators. It is not affiliated with any one national organization, but many of its ideas and precepts have been incorporated into those of SS&C and Project 2061.

skills, suggests that science education reforms of a hundred years ago are not so different from reforms underway today. What is going on? Why do we suggest many of what appear to be the same approaches to teaching science now as then? Have we not learned to do things better in a hundred years?

The author presents some highlights from the periodical literature and a brief introduction to the status and reform efforts of science education in the late-nineteenth century and the late-twentieth century in this chapter. More in-depth discussions and descriptions of the topics introduced here occur in the following chapters.

I. An Introduction to the Status of Science Education in Late-Nineteenth Century Schools

Education literature from the 1880s and 1890s began to address concerns about science education. Educators expressed concerns about the quality and methods of science instruction that occurred in the expanding public schools (Rappleye, 1887; Jackman, 1895; Harris, 1895). Others wrote of problems associated with rote memorization, and the authoritarianism of textbooks and teachers in science instruction (Dryer, 1888; Morrill, 1888; Ballard, 1888; Jordan, 1890; Ward, 1897). Lack of experimentation by students was a source of concern that some science educators cited (Lewis, 1887; Ballard, 1888; Jordan, 1890; Macmillan, 1892). Most science educators described the poor quality of science teachers (Cutting, 1887; Koyl, 1888; Ward, 1897),

lack of equipment (Lewis, 1887; Dryer, 1888; Harris, 1895), and "word-worries"* (Macmillan, 1892), as norms of science instruction in schools.

D.S. Jordan (1890), described school science as "make-believe...not relevant to the child," and overloaded with too many science courses. Some of these same authors suggested *best* methods of science instruction, and in this study the author uses these suggestions to define one view of *reform* in science education of the late-nineteenth century.

Science instruction was not a standard part of most late-nineteenth century high school programs, so one major reform focused on changing the traditional educational agenda. The push to include a wider variety of subjects in the new high schools gained impetus in the late 1880s. The developing scientific and technological society of the late-nineteenth century prompted science educators to respond to a public demand for practical high school courses, which included science. Reformed school curricula started including science courses, just as the traditional curricula always had included the classics -- Latin, Greek, and mathematics.

Science, as a valued discipline, first became established in colleges and universities and later found its way into high schools in response to needs of colleges and universities (Brown, 1896). By 1887, Harvard, under the leadership of President Charles Eliot, gave entrance examinations "...in elementary botany, the rudiments of physics, chemistry, and descriptive astronomy" (Inglis, 1918, p. 507). Other colleges soon followed suit.

* Conway Macmillan (1892), a professor of botany at the University of Minnesota, described the state of botany instruction in high school using the term "word-worries." To him "word-worries" resulted when nature was neglected for the study and memorization of terms from the textbook. To illustrate this point he cited the textbook glossary as "...condensed to the limit of comprehensibility in order that it may include all needed polysyllables for the approaching hour of trial when a flower is to be analyzed. Consequently the pupil is assured that ovules are campylotropous, anatropous, amphitropous, but nowhere is he give the slightest insight into the true nature of an ovule" (p. 465).

High schools responded to the changing requirements for admission to colleges and universities and initiated science courses into their existing curricula. As public high schools began to play an expanded role in the American educational scheme they became more and more the cornerstone for college and university admission. It became important to college bound students that high schools provide the courses necessary for college admission. However, the developing high schools of the nation lacked uniformity in subjects taught, and colleges lacked uniformity in their admission requirements. This lack of uniformity at both ends of the educational network created problems of curricula content for high schools. So, a second major reform faced by the evolving public secondary school system was the development of a uniform curriculum which prepared students for admission to colleges and universities, and at the same time, prepared them for life.

Science classes in secondary schools instructed pupils in the processes and knowledge of science. Elementary school science instruction played an important role in this function, for educators believed that high school students could perform observational skills well only if they had received some rudiments of these in the elementary school (NEA, 1893, p. 139). One author (Morrill, 1888) expressed this concern when he wrote, "If the pupil comes to the secondary school undisciplined in observing, considerable time is required to break up his old habits before new ones can be formed" (p. 405). The development of the faculty of observation was an important goal for elementary science instruction.

Science courses became part of grammar schools' and primary schools' curricula in response to educators' concerns with training the faculties of the mind. Just as colleges influenced high schools in adopting and adapting science into their curricula, high schools influenced common schools' and primary schools' science curricula. Science instruction at

the college, high school and elementary school levels became interdependent during the last decades of the nineteenth century.

In most cases, classroom science instruction did not appear to be the type envisioned by educators such as Jordan (1890), Rice (1893), Jackman (1891, 1894, 1895), Wilson (1899a, 1899b), Parker (1894), or other educational reformers of the time. While many of these science educators called for science instruction guided by student interests and dealing in practical applications (Dryer, 1888, Jordan 1890, Paddock, 1896), descriptions of classroom teaching lead us to infer that a more mechanical, literary, textbook memorization of facts was the reality of the times (Ballard, 1888; Morrill, 1888; Jordan, 1890; MacMillan, 1892; Rice, 1893; Ward, 1897). Meyer (1957), an educational historian, described the state of education at the end of the nineteenth century as "uniform and ordered routine." He said that the school "...arranged its stock of learning as graded and classified subjects, and taught them by a clock like schedule. Teaching was reduced to pumping knowledge into pupils, dosing them massively with homework, and examinations...." He continued by saying that "...though impregnated with high motives, it was obviously more the drill ground than the house of Solomon. Specializing in the gross, it was expected to yield a standardized product" (p.246).

II. An Introduction to the Status of Science Education in Late-Twentieth Century Schools

Science in high schools today assumes a large part of the total curriculum. In most high schools many levels of science instruction exist. There are courses for remedial students, consumer courses, general, academic, and advanced placement courses for

college credit. Each of these types of courses may exist in any or all of the different science disciplines. For example, there may be general biology, consumer biology, academic biology and advanced placement biology. Some educators view the hierarchical arrangement of science courses as a hidden form of tracking that manages to keep out certain classes of students, such as minorities and females, and results in elite science (Kyle, 1991; Aldridge, 1992; Shymansky & Kyle, 1992). The road to further advancement in high technological and scientific careers appears roadblocked to many because of exclusion as a result of tracking. It is not a science for *all Americans* (Aldridge, 1992).

Descriptions of elementary school science reiterates much of what is wrong with secondary science instruction. "Few elementary school teachers have even a rudimentary education in science and mathematics..." is a description of elementary school science given in *Science for All Americans*, (AAAS, 1989, p. 13). Perhaps it is this state of affairs that leads to descriptions of elementary science that mirror those of secondary science -- lack of experience with nature, reading textbooks instead of being actively involved in science, and memorization of terms. Studies reported in the *Science Report Card* (Mullis & Jenkins, 1988; Jones, Mullis, Raizen, Weiss, & Weston, 1992) support this view of science in the elementary classroom. These studies reveal that the most often used instructional method in the science classroom is reading textbooks, whether it was grade 3 or grade 11.

Relevancy is a keyword in science reform efforts and appears to be an answer to some of the concerns mentioned above. New ways of approaching science instruction,

based on constructivist learning principles* influence ideas for the reformation of science instruction (AAAS, 1989; Yager, 1991b; NSTA, 1992a). Combined with relevancy, student-centered and initiated interests, and interdisciplinary approaches to science, constructivism establishes a new research base for scientific pedagogy.

III. Reform

Reform, as defined in *Webster's New World Dictionary*, is a process that seeks to "make better or improve by removal of faults." Synonymous with reform are such terms as "correct, revise, rectify, emend, remedy, or redress" (Guralnik, 1980). Educators often seem to attempt all of these processes, for reform is a frequently used term in educational arenas.

The process of educational reform has long been a topic of interest to many educators. W. T. Harris, U.S. Commissioner of Education 1889-1906, wrote about the "Pendulum of School Reform" in 1888. He expressed the idea that educational reforms tend to occur like the swing of a pendulum, cyclic in nature. Today, we find science educators (Cuban, 1990a, 1990b, Sarason, 1990; Kyle, 1991; Raizen, 1991; Apple, 1992; Linn, 1992; Tobias, 1992) continuing to investigate the phenomena of educational

* Constructivist learning principles as described by the science educator, Robert Yager (1991b), include the ideas that: (1) "Knowledge is not acquired passively," but must involve the student as an active participant (2) "Learning is a product of self-organization and reorganization" (3) Learning does not depend upon what the teacher "teaches", but is an interactive process of information encountered and how it is processed by the student (4) "Learning is dependent upon language and communication...but the use of language *per se* in teaching cannot be a means of transferring information" (5) "... knowledge is not an objective representation of an observer-independent world" (6) "Modern science does not give us truth; it offers a way for us to interpret events of nature and to cope with the world" (7) "...knowledge cannot simply be transferred by means of words without first an agreement about meaning and some experiential base" (pp. 53-55).

reforms. The search for factors that influence reforms, for an understanding of reform processes, and for reasons why most reforms seem to fail when put in practice, are of interest to modern day educators.

In science education, the decade in which reform occurs often serves to identify the reform. The reform efforts that occurred in science education after 1957, with the Soviet Union's launching of Sputnik, and into the sixties, are probably the most often cited programs of reform in science education. This first successful satellite launch by a foreign country caused concern in government agencies and science education institutions about the role and place of the United States in scientific and technological fields. Eager to catch up with the Soviets, the United States invested money and effort to build a better science instructional program in public schools. Reform groups funded through government agencies, primarily the National Science Foundation, developed new curricula and coordinated materials for classroom instructional use.* The goal of these reform efforts was to supply the country with scientists and engineers. Educators, the public, and the government perceived the need for scientists and engineers as great.

Although, the sixties represent one of the better known recent decades of science reform, other decades are known for reform movements. The nature study movement** of the 1890s was another instance of a decade of reform in science education. In fact, each decade seems to spawn its own reform efforts. The 1900s reformed science instruction with the addition of general science to the curriculum, the 1920s reformed science instruction for social control and efficiency, and the 1940s saw science training as

* Some NSF supported science programs were: Physical Science Study Committee (PSSC); Chemical Education Materials Study (CHEM Study); Earth Science Curriculum Project (ESCP); Introductory Physical Science (IPS); Elementary Science Study (ESS) and Biological Sciences Curriculum Study (BSCS). (Duschl, 1990, p.23)

** Nature study was primarily an instructional method used in elementary grades. It provided for the study of common forms of plants, animals, rocks, minerals, etc., that children knew about and could easily be found in their surroundings. This movement is discussed in more depth later in this study.

functional (DeBoer, 1991). The 1990s' reforms call for general scientific literacy for all Americans. Beginning with the introduction of science classes into the secondary school curricula of the late-nineteenth century to the efforts of 1993, reform appears to have been a never-ending process in science education.

1. Late-Nineteenth Century Reform

In this study, reform initiatives of late-nineteenth century science educators are those which incorporate the instituting of science into schools, and those which suggest improvements in instructional methods. Late-nineteenth century science education *reformers* are those people associated with the processes of establishing and teaching science in schools.

Many reformers actively participated in the educational associations of their day. The National Education Association, in particular, served as a springboard for their ideas. In addresses, discussions, articles, and through membership on committees, reformers of the late-nineteenth century expressed their views of science education. These reformers expressed concerns about the lack of science instruction in schools and about the type of instruction that took place in those few schools that taught science.

The work of the Committee of Ten* addressed many concerns of science educators. In a later chapter, the author discusses the report issued by this committee in more detail, but it is important to note that their work played a vital role in establishing and providing uniformity for science courses as part of high school curricula in the United States.

* Commonly used name for the *Committee on Secondary School Studies* established and funded by the National Education Association in 1893. The job of this committee was to establish some uniformity of studies in the secondary schools.

2. Late-Twentieth Century Reform

The United States has undertaken some major reform efforts within the past two decades in science education. These reforms stem from problems identified by the science education community and some government agencies. In many instances, reform recommendations seem to carry with them economic concerns of the nation. For example, *American 2000** includes goals that also incorporate a scientifically literate workforce.

Movements such as the American Association for the Advancement of Science's *Project 2061*, the National Science Teachers' *Scope, Sequence, and Coordination*, and the push towards a *Science/Technology/Society* emphasis, are three major science reforms present today. These three reform movements share some of the same approaches to, and the same philosophy of science instruction for all Americans. However, each retains its own personal agenda. Table 1 provides a summary of some of the major ideas of each of these reform initiatives. In chapter 4 the author presents an in-depth look at the major tenets of each of these three movements.

* *American 2000* resulted from the 1991 National Education Strategy goals adopted by the nation's governors and President Bush. One goal involving science education is: "U. S. students will be first in the world in science and mathematics achievement" (p. 19).

Table 1: Late-Twentieth Century Science Education Reforms

Area of analysis	STS	Project 2061	SS&C
Philosophy of science	Science does not give us truth, but a way to interpret the events of nature and a means to cope with the world.	Science is a social activity that also incorporates human values. Things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic, study.	Science involves more than just facts. It also involves belief. We create models and theories to account for facts, observation, and empirical laws. These hold true only as long as they are successful in explaining all aspects of the phenomena.
Psychology of learning	Based on constructivist learning theory.	Based on constructivist learning theory.	Based on constructivist learning theory.
Aims of	Recognizes four main goals: (1) Science for personal needs (2) Science for resolving societal problems (3) Science for career awareness and (4) science for preparation for further study.	To produce scientifically literate citizens. To develop habits of mind needed to become compassionate human beings, able to think for themselves and to face life head on.	To make scientific literacy a goal for all students. To teach science in a coordinated way from concrete to abstract with practical application. To teach basic scientific concepts through experience.
Role of the Laboratory in	To provide opportunities to study real-life, personal, and societal science and technology; to promote group learning. The path to solution is more important than right answers.	To get acquainted with things around them; to question; to observe, collect, sort, classify, in order to find answers to their questions; use of evidence important.	To provide hands-on experience with phenomena before terms are defined or concepts named. Examine results and arrive at relationships through own analysis
Problems cited by	Lack of framework which emphasizes application and problem solving. Testing, memorization of facts; not relevant to students.	Most Americans are scientifically illiterate; US students near bottom in international tests; poor preparation of teachers; teachers teaching out of content areas; use of textbooks support rote learning of facts.	Learning of facts; tradition; lack of scientific literacy; students study too little science; present system of sequencing excludes some from science courses and careers.
Reforms seen as needed by	Students actively involved in relevant problem solving and decision making situations; Using student ideas and questions to guide lessons; group activities; focus on the impact of science on each student.	Scientific literacy for ALL students; Common core of learning; interdisciplinary approach; decrease use of textbooks- depend more on class discussion and investigation; teachers as professionals; less is more; use of scientific knowledge for social purposes and for the individual.	Develop a carefully sequenced well-coordinated instructional program in all sciences that all students study every year for seven years so that students acquire a greater depth of understanding in science.

IV. About This Study and Its Historical Perspective

Common themes about science education and its reforms emerged from the review of literature of the late-nineteenth century and the late-twentieth century. The author coalesced these themes into five major headings for purposes of comparative ease between the two time periods under study. These five headings are:

1. The philosophy of science and the psychological basis of learning science.*
2. The aims and goals of science education.
3. The role of the laboratory in science instruction.
4. Problems identified by each era as affecting science education.
5. Reforms suggested by the era to rectify identified problems.

The author used these headings to compare prevalent views of science education reforms of the two different time periods. In Table 1 the author used these headings to summarize the three major reform movements of the late-twentieth century. Table 2 displays a side by side overview of ideas about science education that the author condensed from late-nineteenth and late-twentieth centuries' literature. In these two tables, the author provides some background information concerning late-nineteenth century's and late-twentieth century's philosophy, aims, problems, and reform efforts in science education.

It was the aim of the author to explore the reform movements of the two time periods in an attempt to characterize common and uncommon factors associated with the

* There was little separation between philosophy and psychology in the late-nineteenth century education, therefore these two areas appear together in the tables used to compare ideas from both time periods. The author does separate the overall area into two separate parts through the use of dashed lines as a means of showing that these two are more separate in late-twentieth century education.

Table 2: Science Education -- Summary of Late-Nineteenth and Late-Twentieth Centuries' Ideas of Science Education

Topic	Late 19th Century	Late Twentieth Century
Philosophy of science of and	Baconian view of science; Triumph of man over nature; Positivistic approach; Science = Truth; Pestalozzi, Herbart, Spencer, and Huxley influential.	Post-positivistic view -- Science does not equal truth.-- Science = socially constructed knowledge. Science seen as social activity with human values. Science is way to interpret events of nature.
Psychology of learning	Apperception, moral character, mental discipline and mental faculties prevailing educational learning theory.	Constructivism a prevalent educational learning theory of reform movements.
Aims of	Develop personal faculties of observation, reasoning, thinking -- Scientific habits of mind; Power to deal with life. Develop interest in nature. Practical use of science processes in everyday life Facts secondary.	Produce scientifically literate citizens. Develop scientific habits of mind to become compassionate human beings--To think for selves , to face life head-on. Personal, social, career, and scientific preparation goals.
Role of the laboratory in	Key to training of mental faculties in science processes.. The only way to teach science. Experiments were to be done by pupils to discover, illustrate, or demonstrate natural laws. Main goal -- develop powers of observation etc.	Hands-on important, to study real life situations. of personal and societal issues. Relevance. To teach skills to observe, classify, sort, collect, solve problems. Examine data to arrive at relationships.
Problems cited by	Poor quality texts; Unprepared teachers; Dependence on textbooks; No laboratory work; Isolation of subjects; Memorization of terms; Teaching too much; Lack of relevance.	Science not relevant; Too much rote memorization.; Study books, not things; Scientifically illiterate Americans; Bottom of international tests; Students take too little science; Elitism of science sequencing. Too much dependence on textbooks.
Reforms seen as needed by	Hands-on experimentation by pupils; Fewer courses; Same science for all; Teach science for practical value; Little use of texts, more use of nature; Better teacher preparation; Proceed from concrete to abstract and known to unknown.	Science for all; Students actively involved; Relevant issues and concerns studied; Interdisciplinary approach -- Show science as involved in society and technology; Less is more; Scientific knowledge for personal and social purposes; More science for all; Teach Problem solving.

reform periods. In the following chapters, the author attempts to answer questions such as; *Are there common factors that help initiate and direct these calls for reforms? Are reforms of these two decades before the turn of the centuries really as similar as they seem? What can history tell us about the reform processes? What can we learn from previous experiences with similar reforms?*

If the two reform periods under study are as similar as they appear, and if there are some common factors between the two reform periods, then perhaps a picture of how science education changes, why it changes, who changes it, and the role of reform movements will emerge. For those involved in science education, this would be useful background with which to view what is occurring today.

Bybee (1982), a noted science educator, stated that there is a regrettable lack of historical research literature on science education. He observed that there are lessons to be learned from analysis of our past and that "...we can certainly improve our present and future development through an increased historical perspective" (p.1). Consequences and alternatives that may otherwise be overlooked can appear if we have a historical perspective (p.2). It is through such a perspective that this study examines ideas of science education reform in times that are one hundred years apart.

A historical study about reform processes and reform ideas can perhaps enlighten the role of reform in science education. Science educators Shymansky and Kyle (1992), said that an understanding of the history of science education is a necessity to establishing a research agenda for addressing critical issues of science curriculum reform. Perhaps an understanding of relationships between science education, the scientific community, the science teacher-educator, and the scientific and technological world may be able to inform reform processes in science education today.

It is not expected that a historical perspective will keep science educators from making errors in the struggle to provide quality science education. The history of science education is important to science educators in much the same way that the science educator sees a need for students of science to have a historical perspective on science -- history provides a picture of the road to where we are.

An understanding of the nature of science education and what it is about, is as important for the science educator and the science education reformer as is the history of the development of scientific knowledge. Such knowledge of the nature of science education reform helps educators understand what has taken place before and what has been tried and believed in the processes of science education reform. Although he was not a science education reformer, former U.S. President Harry Truman made a statement that provides insight on the role of history in understanding the world -- "There is nothing new in the world except the history you do not know" (Miller, 1973, p. 26). Perhaps it is some of the history we do not know (or remember) about science education reform that will enlighten the efforts of today's reformers.

In the following chapters, the author describes science education and its reform efforts situated in the world of late-nineteenth century and late-twentieth century America. Throughout chapters two and three, the author explores factors that influence the nature of science education and reform in a search for common elements that seem to stimulate similar reforms. In chapter four, the author examines differences and similarities between the two eras under study, and in chapter five reaches some conclusions about reform efforts in the two eras and offers a recommendation for action in reforming science education based on the conclusions.

CHAPTER 2

FACTORS ASSOCIATED WITH AND INFLUENTIAL ON REFORM PROCESSES OF LATE-NINETEENTH CENTURY SCIENCE EDUCATION

I. The Times

The Gay Nineties, the Gilded Age, and the Mauve Decade describe the aura of the late-nineteenth century. One modern writer (Panati, 1991) described this as a time when America saw the "...waning of Victorian life and the dawning of modern America." The previous two decades of prosperity, scientific advancement and technological gains exalted the role of science and technology in society. It was a time of inventions, innovations, and system building. The late-nineteenth century produced the incandescent light, wireless telegraphy, the phonograph, aluminum by electrolysis, the internal combustion engine and the *New World Symphony*. The United States after 1870 "...created the modern technological nation" (Hughes, 1990, p. 3). It was a time when America discovered itself in its own inventive and creative genius.

A spectacular display of American industriousness was the Chicago's World's Columbian Exposition in 1893. This was one of many such expositions of the late-nineteenth century.* Americans eagerly displayed their scientific and technological achievements to the world. The historian, Wim de Wit, described the character of the World's Columbian Exposition as one that "...emerged out of attitudes of cultural

* America hosted other major international expositions in the late-nineteenth and early twentieth centuries. Fairs were held in Omaha (1898), Buffalo (1901), St. Louis (1904), Portland (1905), Seattle (1909), and San Francisco (1915) (Harris, de Wit, Gilbert, & Rydell, 1993, p. 10).

inferiority..." that Americans experienced in the late-nineteenth century. Americans "...perceived a lack of respect from Europe" and this fair was an attempt to show-off American ingenuity and products in order to establish the United States as a world leader (Harris, de Wit, Gilbert, & Rydell, 1993, p. 43).

The expositions at the Chicago's Fair, as described in the "Editor's Table" of *Popular Science Monthly* (1893), marked "...the utmost achievement of the kind that the world has beheld" (p.123). The vast numbers of displays were overwhelming. The editor suggested that only those who went to the fair with the intention of studying a certain one thing would gain some benefit from the fair. The other alternative was that one have enough time to devote months of examination to the fair.

Technology ruled the exposition. There were exhibits showing new processes and technologies of agriculture, industry, and mining. Buildings' names reflected the technological spirit of the fair as well as their contents -- Machinery Hall, Electricity Building, Shoe and Leather Building, Mine and Mining Building, the Transportation Building and the Manufacturer's and Liberal Arts Building. *Popular Science Monthly* cited new technological innovations* such as the Jacquard loom and a new indexer for libraries, both operating on the principle of perforated cards.

The fair did not exclude education. The "Editor's Table" described the educational exhibit as "repetitious" and "often of poor quality." However, the editor saw new processes of education, such as manual training, instruction in sewing and cooking, kindergarten, and instruction "...to the all-round development of the senses..." as an indication that old *clerkly* instruction was on the way out (p.126).

* One new technological innovation introduced at this fair was the Ferris wheel (Harris, et.al., 1993).

The educational exhibit located in the Anthropological Building impressed the editor the most, and brought back some enthusiasm. Here was the psychological exhibit and laboratory of Prof. Jastrow.*

Here, amid the most extensive collection of appliances ever brought together in America, quantitative tests of faculty are made: the effect of this new science of experimental psychology on education must be to sift out good methods of instruction from bad, and in the fullness of time to awaken and direct in the individual mind the ambitions which to-day either remain unaroused or ignorantly run riot (p. 126).

Psychology and its use of scientific methods began to establish a foothold in late-nineteenth century educational processes.

The American system of manufacturing led to an industrialization process that provided new jobs, new life styles, and more money for many. The educational historian, Tyack (1974) wrote that in 1860 the United States lagged behind England, France and Germany in industrial output, but that by 1894 the United States produced almost as much as the three combined.

With the availability of jobs, Americans moved from farms to cities. The traditional extended family changed as they moved into urban areas. The father worked outside of the home and became part of the industrialization process. His presence and authority was not felt at home as much as it had been earlier. The role of children also changed for they

* Joseph Jastrow was professor of psychology at the University of Wisconsin from 1888-1927. He was head of the psychology section at the Chicago's World's Columbian Exposition (Collier's Encyclopedia, 1969, Vol, 13, p. 506).

no longer had responsibilities of farm life. They became freer from parental control. What was to become of the children? Some worked in factories, but after child labor laws passed, concerns arose for the moral character of children in the *wicked* and crowded cities. Schools became an answer. "If family discipline and the traditional village restraints broke down, then the school must fill the moral vacuum" (Tyack, 1974, p.68).

School enrollments soared in large cities. Perkinson (1991), an educational historian, reported that the number of 5-18 year olds in school rose from 6 1/2 million in 1870 to 15 1/2 million by 1880 (p.70). A report from Brooklyn schools (1893) showed that enrollments in 231 classes out of 377 were between 60 and 70; 65 classes had between 70 and 80; 22 classes had between 80 and 90; 18 classes with between 90 and 100; 2 classes had between 100 and 110; 16 classes had between 120 and 130; 4 classes with 130 to 140; 2 classes with 140 to 150; while one class reached the enormous total of 158 (Penniman, 1895). The author stated that 1894 was probably worse than 1893. There was an annual increase in enrollment of 5000, while only 1800 additional places became available.

The surge of new students in Detroit created a situation where "...seventy-five percent of all our children who enter school have left at the age of twelve" (Penniman, 1895, p. 204). The author reported that many systems and schools had to use basement and attic rooms as classrooms. Most larger city schools lacked sufficient space as well as sufficient numbers of teachers. With classrooms of 50 to over 100 students, the teacher's survival depended upon rote learning and recitation by pupils. It was into this environment that science instruction was introduced.

II. Science, Science Education, and the Science of Education

One science educator, (Cobb, 1899), wrote of the "previous thirty years of science teaching" in the United States (1869-1899). In his article, he listed innovations that did not exist one hundred years earlier. Among his list were stock-ticker, telephone, dynamo, Rotengen rays, liquefaction of gases, trains with sleeping and dining cars, and air-brakes. He concluded that with the field of science* daily extending "...it is true to an extent that it was never before true that it is no light task for one to overtake the present state of the world's knowledge even within narrow limits" (p. 1100). The author saw in the public awareness of the present state of technological and scientific gains signs of approval for the inclusion of science instruction in schools. Besides this perceived public approval for science instruction in schools, there were other factors, foreign factors, that stimulated the demand for science courses and scientific methods in American schools.

1. Non-American Influences on Secondary School Science:

Foreign nations influenced the American curriculum in the 1880s and 1890s. Meyer (1957) reported that for most of the nineteenth century the best American pedagogy was alien in origin. He suggested that the reason for this was the involvement of American educators with practical action. They were busy trying to make a common school, building school systems, getting financial support, and securing everyday operations of schools. Little time was left for what seemed like remote processes of pedagogy. It was easier to turn to Europe for these, and American educators did just that. Ideas and instructional methods of educators from abroad filtered into science curricula of American schools.

* Cobb's use of the term "field of science" in reference to technological innovations, points out the concept of "technology" as included in the definition of science in late-nineteenth century society. Technology was the product of scientific knowledge. All of the innovations Cobb described were technological.

What was going on in European education dominated the interest of American educators such as, Eliot, Rice, DeGarmo and Harris. Eliot spent two years studying chemistry and pedagogy in Europe (Sizer, 1964). Rice, a physician, spent 1888-1890 in Germany where he studied psychology and pedagogy at the Universities of Jena and Leipzig. His interest in prevention of disease among children led to his study of child development. Rice later left medicine and undertook an eight year study of one hundred or more school systems in the United States and Europe (Ohles, 1978). Under the sponsorship of *Forum* magazine, he published a series of articles that revealed the "mechanical" textbook instructional nature of American schools (Rice, 1893).

The German educator and philosopher, Johann Friedrich Herbart influenced the American educator Charles DeGarmo while he worked on his Ph.D. in Germany. (Ohles, 1978). He became an avid supporter of Herbart's ideas in the United States and, in 1892, published *The Essentials of Method* in which he presented Herbart's educational theory of apperception.

Apperception is "...the process of giving significance to facts by relating them to our more firmly established knowledge" (DeGarmo, 1909, p. 24). Herbartians believed that "...all mental activity presupposes and starts with knowledge gained through the senses..." (p. 13). Herbartians developed a five step teaching method:

- (1.) Preparation
- (2.) Presentation
- (3.) Association
- (4.) Generalization and
- (5.) Application (Meyer, 1957, p. 231).

This method of instruction was the fashion of late-nineteenth century pedagogy and Herbart's ideas flourished in the United States between 1875 and 1925. They were not dispensed with until more advanced ideas of psychology and sociology of the twentieth century replaced them (Meyer, 1957).

Using the principles of apperception as a guide, DeGarmo described the essentials of *correct methods* of teaching as:

- (1) apperception and the formation of individual ideas,
- (2) transition from individual ideas to general notions such as rules, definitions, principles, etc., and
- (3) the application of these truths to concrete facts (p. 97).

Science instruction very neatly fit into this format. It provided for the use of the senses in observational work, for the formation of individual ideas as depicted in laboratory drawings and descriptions, for the development of general notions through the inductive approach, and the application of this knowledge in the everyday world.

The German philosopher, Hegel,* influenced the ideas of W. T. Harris. In a comparison of German education with that of the United States, Harris (1891) praised the idea of the "self-activity" of the child as the "one object of education." Self-activity was a process in opposition to memorization and "constraint in conduct or intellect" that he saw evident in American schools. Self-activity would awaken the mind and give critical alertness.

* George Wilhelm Friedrich Hegel's method is known as *dialectic*. It consists of thesis, a statement about a thing; an antithesis, a contrary statement about the same thing; and synthesis, a third statement synthesizing the first two and making a third statement that demonstrates a positive insight into the thing (Kiernan, pp. 78-80).

Harris depicted the German nation as one that was "knowledge-loving" while the Anglo-Saxon nations loved "adventure." Because of these natural tendencies, he said that the American child was restless and in need of more discipline by teachers. Therefore, American teachers spent more time on control rather than on instruction. "Memorized work may be tested with the least possible trouble--it does not distract the attention of the teacher from the work of keeping order and discipline in his school" (Harris, 1891, p. 199).

Other educators (Smith, 1882; Mayo, 1887; Williams, 1892; Gage, 1896; Aspenwall, 1902; Waldo, 1902) also cited better pedagogical methods of German education. Smith (1882) wrote that while we were busy "balancing" our scholars, teachers, materials, and funds against foreign countries, "...we scarcely note[d] the degree by which they are [were] surpassing us in the adoption of elementary schools to the conditions of practical life" (p. 382).

Waldo (1902), in a look at nature study, pointed out that in German schools such a study would be under the direction of a "...university graduate who has earned his doctorate by a long continued study of the very branch of nature which he is called upon to teach, while in our own schools too frequently but a year or two of special study, perhaps supplemented by a few weeks instruction in a summer school, is the preparation on the part of the teacher" (p. 36).

Aspenwall (1902) also cited the better preparation of German teachers. For the Secondary Teachers' Certificate in Prussia he gave the following requirements:

1. The candidate must have graduated at a recognized secondary school, and have passed with credit to the university.
2. He must have spent at least three years at the university.

3. He must have specialized in one subject, and studied one or two allied subjects.
4. He must have studied religion, philosophy and pedagogy.
5. When the candidate has fulfilled these requirements, he must present himself before a commission for the state examination. If he passes, he enters a course of special professional training as a candidate.
6. He must spend one year in a pedagogical (*sic*) seminary in the study of the theory and practice of education.
7. If successful in the seminary year, he enters upon regular work in the school-room for a trial year. He teaches in a recognized school under the direction of the regular teachers, but receives no salary. When the candidate has fulfilled these seven requirements, he is a qualified teacher (pp. 30-31).

The Englishmen, Herbert Spencer and Thomas Huxley also made impressions on some Americans involved in science education in the late-nineteenth century. Both of these men held science in high esteem in the culture of their times. In the mid-1800s, when Spencer asked, "What knowledge is of most worth?" his reply was, "Science." Science was the knowledge of most worth "...for direct self-preservation..." in terms of health. Science was the knowledge of most worth "...for indirect self-preservation..." in terms of livelihood. It was also "...for the discharge of parental functions...for interpretation of national life...for the most perfect production and highest enjoyment of art... and ...for the purposes of discipline--intellectual, moral, and religious..." (Spencer, 1963, p. 93-94).

In a speech given in 1869, Huxley advocated that science instruction was different from other disciplines in that science instruction prepared students for common life. Huxley said skills associated with science training, like observing, interpreting, and

reasoning were applicable to the business of life. In describing how to best obtain these skills, he said that reality must be given to the teaching of science. Object-lessons, hands-on experiences with nature, letting the student see, feel, and doubt, "...until he is compelled, by the absolute authority of Nature, to believe that which is written in books" were ways to accomplish the reality of science (Huxley, 1902, p.114). He said that the intellectual habit was more important than the small amount of information that one poured into the mind of the student. Huxley stressed the importance of the processes of science over the products of science, a theme common among late-nineteenth century American science educators.

Besides being the important result of science instruction, the processes of science became important to late-nineteenth century educators in the establishment of a science of education. In a society that was building new systems of industry, the push for a system of education became a concern. Scientific and technological gains influenced schools -- "...one may claim that urban education in the nineteenth century did more to industrialize humanity than to humanize industry" (Tyack, 1974, p.72).

The times appeared ready for public schools to include science courses and scientific methods of teaching in secondary school curricula. A great stimulus for this action occurred on July 9, 1892 when the National Education Association formed a committee to examine the structure of the American high school.

2. The Committee of Ten and Secondary School Science:

Financed and backed by the National Education Association, the *Committee on Secondary School Studies*, better known as the Committee of Ten, Table 3, surveyed high schools across the United States and found as many as forty different subjects taught in these schools (NEA, 1893). The Committee's purpose was to establish some uniformity

Table 3: The Committee of Ten

Name	Position
Charles W. Eliot	President of Harvard University; Chairman
William T. Harris	Commissioner of Education
James B. Angell	President of University of Michigan
John Tetlow	Head Master of the Girls' High School and the Girls' Latin School
James M. Taylor	President of Vassar College
Oscar D. Robinson	Principal of the High School, Albany
James H. Baker	President of the University of Colorado
Richard H. Jesse	President of the University of Missouri
James C. Mackenzie	Head Master of the Lawrenceville School
Henry C. Knig	Professor in Oberlin College

in the numerous secondary school programs they found existing throughout the United States.

In its attempt to provide guidance for high schools, the Committee of Ten selected nine categories of subjects for the organization of secondary school curricula. Many of these nine subject categories were traditional languages and mathematics, but three were new science courses. For each of these nine categories, they appointed a ten member conference to address a list of questions developed by the Committee of Ten. These questions dealt with the age at which a study was to begin, how much time should be given to it, what topics were to be covered, what should count towards college admission, best methods of teaching, testing for college admission, and how courses should be treated for non-college bound as well as for those going to college.

The three science conferences established by the Committee of Ten were: the conference on Physics, Astronomy, and Chemistry; the conference on Natural History (Biology, including Botany, Zoology, and Physiology); and the conference on Geography (Physical Geography, Geology, and Meteorology), Table 4.

Table 4: Members of the Science Conferences of the Committee On Secondary School Studies

Conference on Physics, Astronomy, and Chemistry

Name	Institution
Professor Brown Ayers	Tulane University
Irving W. Fay	The Belmont School, California
Alfred P. Gage	English High School, Boston
George Warren Krall	Manual Training School, Washington University, St. Louis
Professor William W. Payne	Carleton College, Minn.
William McPherson, Jr.	Toledo, Ohio
Professor Ira Remsen	Johns Hopkins University
Professor James H. Shepard	South Dakota Agricultural College
Professor William J. Waggener	University of Colorado
George R. White	Phillips Exeter Academy, N.H.

Conference on Natural History (Biology, including Botany, Zoology, and Physiology)

Name	Institution
Professor Charles E. Bessey	University of Nebraska
Arthur C. Boyden	Normal School, Bridgewater, Mass.
Professor Samuel F. Clarke	Williams College, Mass.
Professor Douglas H. Campbell	Leland Stanford Jr. University, Calif.
President John M. Coulter	Indiana University
Principal S.A. Merritt	Helena, Mont.
W. B. Powell	Superintendent of Schools, Washington, D.C.
Charles B. Scott	High School, St. Paul, Minn.
Professor Albert H. Tuttle	University of Virginia
O. S. Westcott	Principal of the North Division High School, Chicago

Conference on Geography (Physical Geography, Geology, and Meteorology)

Name	Institution
Professor Thomas C. Chamberlin	University of Chicago
Professor George L. Collie	Beloit College, Wis.
Professor W. M. Davis	Harvard University
Delwin A. Hamlin	Master of the Rice Training School, Mass.
Professor Edwin J. Houston	Central High School, Philadelphia
Professor Mark W. Harrington	The Weather Bureau, Washington, D.C.
Charles F. King	Dearbon School, Mass.
Francis W. Parker	Principal Cook County Normal School
G. M. Philips	Principal of the State Normal School, Pa.
Professor Israel C. Russell	University of Michigan

Each science conference met December 28-30, 1892 to address the questions proposed by the Committee of Ten. They met at the University of Chicago, and in three days developed recommendations for the teaching of their disciplines in secondary schools.*

The report issued by the Committee of Ten created much discussion and debate within the educational community, and resulted in changes in secondary school curricula. One change was the inclusion of courses other than traditional classical studies. The Committee of Ten developed several alternative curricula from which high schools could choose. There was a Classical program, a Latin-Scientific, a Modern Language and an English program. Each of these varied in the amount of languages, mathematics and science required (NEA, 1893). The educational historian TheodoreSizer (1964), stated that the work of the Committee of Ten was "...plainly a compromise between traditions in American secondary education and pressing changes in the intellectual climate; and these were largely the result of the rise of science" (p. 143).

High school science instructional methods recommended by the Committee of Ten used observational laboratory work as their basis. All of the individual reports from the different science conferences stressed the development of observational skills, reasoning abilities, expression, and judgment as outcomes of science education.

* In addressing the questions dealing with the age at which the study of science should begin, all the science conferences recommended that science instruction begin during the earliest possible grades. This opened the door for these secondary and college men to get their ideas of science instruction into curricula of grammar and primary schools. The Natural History conference even developed curriculum guides for elementary grades. Disgruntled with "...men largely concerned in secondary education...to shape elementary courses of study to accord with the fixity of their [secondary] curriculum..." elementary schools requested and got their own committee to study elementary education. In February 1893, the NEA appointed the Committee of Fifteen. Dr. W.T. Harris and fourteen public school superintendents from all over the country made up this committee. The report of the Committee of Fifteen was to supplement the report of the Committee of Ten (Rice, 1895a). However, the work of the Committee of Fifteen did not accomplish much in the area of providing guidance in instructional pedagogy for elementary teachers, and it did not attain the same important status as the Committee of Ten.

The educational historian Inglis (1918), said that the recommendations of the Committee of Ten accomplished much to organize the work in natural sciences.

- (1) They tended to standardize the sciences to be studied.
- (2) They tended to standardize the order in which they would be studied.
- (3) They gave great impetus to the study of the natural sciences as sciences with emphasis on laboratory work.
- (4) They emphasized the study of some natural science by every pupil (p. 509).

Ultimately, the different science conferences' recommendations supported those voiced in the general recommendations made in the summary report by the Committee of Ten:

- (1) Each subject was to be treated in the same way for all pupils.
- (2) Enough time was given to each subject so that the pupil could get from it "the kind of mental training it was fitted to supply.
- (3) Principal [sic] subjects were put on approximate equal time allotment.
- (4) All short information courses were omitted.
- (5) There was to be continuous instruction in each of the main lines of study -- languages, science, history, and mathematics and
- (6) Pupils were to be prepared for admission to appropriate courses in any American college or university on the existing requirements and would also meet new college requirements (NEA, 1893, p. 44).

Recommendations of the Committee of Ten were a step in the direction of a working relationship between public high schools and higher education (Krug, 1964).*

In an era of great scientific and industrial changes, there arose a public cry for a more practical education. The Committee of Ten recognized chemistry, physics, astronomy, natural history, and geography as legitimate, practical needs in the *new education* of late-nineteenth century America. Science courses, in their practical application of scientific processes and ways of thinking to everyday situations, were preparation for life. Factual knowledge, needed for college admission, was a secondary aim of science instruction. The report of the Committee of Ten provided the necessary authority for the inclusion of science courses in secondary schools.

3. The Science of Education:

The advance of scientific knowledge and technological processes in the late-nineteenth century permeated the educational agenda. Scientists and science educators of the late-nineteenth century viewed the world in terms of objective reality. Nature could be understood and conquered for the good of humanity through scientific processes (Ballard, 1888; Allen, 1889; Harris, 1891; Skinner, 1897). If scientists and inventors solved problems of the new industrial age, if they provided technological advancements that improved the quality of life through the use of scientific processes, then surely these processes could only produce good when applied to education.

* When the Committee of Ten recommended that all subjects be treated equally for all students, whether they were going to college or not, some educators interpreted this to mean that in designing the high school curriculum to meet the needs of colleges and universities, [as it appeared to some educators that this is exactly what the Committee of Ten did], that in reality, this curriculum equated the needs of students going to college to those needs for all students (Cuban, 1990b). In other words, the courses good for college admission were seen as good for preparation for life. Krug (1964) said that this was a "...fascinating anachronism, for most of the subjects included by the Committee of Ten were in 1892-1893 regarded as preparatory for life, rather than college" (p. 86).

In the last decades of the nineteenth century, writers began to use scientific terms and processes to describe education. Education was in the process of becoming a science. Principal C.H. Henderson (1894) argued that any branch of knowledge could become a science when one established the relationships between cause and effect. Henderson applied the concept of causality to education. Education, he explained, could become a science when one studied the child as an "organic unity" and determined the causal relationships that existed between the body and spirit of the child. Thus a *new education* with a scientific approach to instruction began in the late-nineteenth century.

One method of scientific reasoning is induction, arriving at generalizations based on many independent sense experiences and observations. Late-nineteenth century science students and scientists used inductive processes as a method of discovering scientific *truth*. When educators applied inductive processes to educational pedagogy, they created the idea of a *science of education* called *instruction* "...a technique for transmitting knowledge to pupils through their senses or sense experiences" (Perkinson, 1984, p. 11). With this pedagogical idea, laboratory instruction and its involvement of the pupils' senses in observation became an important part of science classes.

Scientific processes also became involved in the development of social sciences, such as psychology. Understanding and measuring the physical and mental growth and development of students became a way of putting scientific processes to work for educational gains. As noted earlier, the editor of *Popular Science Monthly* put much hope for better means of education in the procedures he saw in the psychology laboratory of Professor Jastrow at the Chicago's World's Columbian Exposition. The science of psychology appeared to hold great promise for education.

Influenced by scientific methods, the science of the mind became the foundation for a science of education. However, many traditionalists viewed with suspicion scientific

processes, as exemplified by psychology. A Unitarian Minister, A.D. Mayo (1887) called for a "special watchfulness" in the new interest of psychology. He viewed psychology as an amoral attempt to explain the mind. Mayo referred to the psychologist as a "...little, shallow, materialistic professor...pushing his theory of man minus soul and a universe without a God as the basis of the entire system of instruction for American youth" (p. 233).

Yet, the ideas of a natural progression of growth and development of children persisted and by the turn of the century a science of the mind began to exert influence on educational processes and pedagogy. Concepts of how students' minds naturally develop and grow became an educational concern, one that felt the influence of a scientific concept--evolution.

4. Natural Progression and Secondary School Science:

In 1859, with the publication of Darwin's *Origin of the Species*, a new era in scientific thinking began. Ideas of natural progression and development provided by the theory of evolution extended into society generally and into education specifically. An "Outline of a General Course Based on Evolution" published in *Education* in 1888 by the high school teacher, Lillie J. Martin, began with, "No scientific theory has yet been shown to be fundamental to all the sciences. Evolution is rapidly assuming this position" (p. 440).

The fingertips of evolution reached not only into biology and geology, but into all sciences and into pedagogical ideas about education. Martin described the evolutionary ideas of natural progression as the guiding principle in classifying sciences--a classification based on matter relationships and not based on artificial, logical thought classifications of man. She saw the artificial classification systems of the sciences, such as biology

chemistry, physics, etc., leading students to forget one branch of science as soon as another study began. Logical classification seemed, to her, to lead to isolated subjects.

Martin called for "...setting the student at work upon a single thing... and have him study it in the light of the various sciences" (p. 442). She said of the student, "Through his senses he must learn that there is a connection between the sciences, then his mind will be ready to perceive that there are deeper relations than at first appear" (p. 444).

Other secondary science educators (Dryer, 1888; Jackman, 1896; Weed, 1896; Richardson, 1899) advocated interdisciplinary approaches, a form of natural progression, for secondary school sciences. Usually they suggested this as an integration of various science courses with drawing and composition. One educator (Weed, 1896) gave an example of an interdisciplinary course that he employed. It involved teaching biology and English, coordinated through laboratory drawings and descriptions. He required students in his botany class to make detailed drawings of plants and some of their special parts. With their drawings completed, students wrote themes describing their plants using specific titles provided by their instructor, such as "A Description of the Arrow-leaved Violet" or "The Leaves and Blossoms of the Mayflower."

These students also attended an English class that required one theme a week. The botany instructor arranged with the English instructor permission for his students to submit one of their botany themes for the English requirement. This coordination of botany, drawing, and English composition seemed to the author to provide "...much valuable training not to be precisely classified under any of these heads." This practice was a very educative experience for the students, according to the botany instructor.

This was an unusual practice for secondary schools. Although this is one example of an interdisciplinary approach attempted in one secondary class, there was no evidence in the literature of the existence of a total interdisciplinary science course. The scientific

approach to curriculum design resulted in no interdisciplinary courses at the secondary level and science courses remained categorized, man-made, logical entities.

The use of evolutionary ideas of natural development when applied to students' mental growth met with more success. The evolution of the individual became a new scientific concern of the educational process and the age of child-centered instruction dawned.

5. Natural Progression and Elementary School Science

Jackman (1891, 1894), Clapp (1893), and Wilson (1899a), were a few late-nineteenth century science educators who advocated a child-centered approach to instruction in elementary schools. Nature study was an attempt to bring the elementary child to the center of the educational process. Grammar and primary school science educators wanted to awaken the interest of pupils in nature. Before the 1880s, object lessons* accomplished this goal in grammar schools. Object lessons involved a method of instruction by which the teacher presented an object for students' observations. A series of questions guided students in their observations until the object under study was well understood.

By the mid-late 1890s, object lessons in science were on their way out as a result of their lack of flexibility and "hollow formalism." The method gradually developed into another means of getting children to "commit to memory a massive collection of facts" (Meyer, 1957). The normal school teacher, Elizabeth Brown, in 1896, wrote of object lessons as ancient history. She pointed out the lack of relationships between objects

* Object lessons were developed by the Swiss educator Pestalozzi. This method of instruction reached its prime in the 1860s-1870s in the United States. Edward Sheldon of the Oswego Normal School was the main proponent of this method. He adopted his object lesson methods from his study of this method in England.

studied from day to day. One day's "object" would in no way relate to the "object" of the next day, for it was the "teacher's fancy or convenience" that determined what the object was.

The nature study movement replaced object lessons and became the elementary school's method of science instruction in the last two decades of the nineteenth century. Nature study typically involved the study of "...plants, minerals, animals, natural phenomena, elementary physics, and chemistry" (Boyden, 1892, p. 479). Students observed first-hand nature that was known, familiar, and close around them.

In a child-centered approach, students' interests guided the study. One means of situating study on the child's interests was through student collections. The normal school teacher and principal Boyden (1892), wrote that teachers reported over three-fourths of their students made their own collections as well as adding to the school's collection. He said that science instruction in the elementary school showed many advantages when studied in association with language and drawing. Correlation of science with other subjects like language and art was a way to "...enhance their meaning for the child..." (Raisien, 1991, p.8).

From the literature of that time period, it appeared that child-centered approaches applied more to grammar and primary schools than it did to secondary schools. Literature about secondary schools and science instruction dealt mainly with subject matter. What appeared to be important concerns at the high school level was *what* was to be taught, in *what order* it was to be taught and *to whom* it was to be taught.

The only indications of a student-centered approach in secondary schools, were suggestions made by a few authors such as, Mowry, 1887; Dryer, 1888; and Jordan, 1890. They recommended using what was known, relevant and of interest to secondary

students. Of course, this interest was organized around a specifically sequenced, subject-oriented curriculum.

III. Aims of Science Education

1. Mental Discipline and Scientific Habits of Mind:

Tradition was a stumbling block to some educators. The biologist, Coulter (1893), saw the problem before educators as that of adapting "...their schemes to rapidly changing conditions." He recognized that the "power of what has been" was very prevalent in education and that "...it is hard to banish all predispositions and face the problem with a judicial mind" (p. 141).

As the new education of the late-nineteenth century began to incorporate scientific processes, the concept of a science of education aided in determining instructional methods and aims of all subjects in schools, not just science courses. Secondary courses had to fit into the scientific atmosphere that permeated education at this time. All education was to proceed through processes of inductive reasoning, observation, analysis, interpretation, sensory experiences, and mental discipline (Eliot, 1898).

Science instruction, however, had a special role in this new scientific education. Science was the one subject that alone could best teach those skills and processes that students could use in all other areas of study and in real life situations. This was a main justification for instituting science courses into high school curricula; science could furnish a special kind of training in mental discipline that no other courses could do (Spencer, 1963 (circa 1855); NEA, 1893, Eliot, 1898; Huxley, 1902).

The addition of science courses in American schools could have been in response to the direct recognized benefits of science and technology in society (such as those earlier cited by Cobb), but this does not appear to be entirely the case. Science education was not introduced to produce scientists, technologists or inventors. Science instruction provided the common man with common sense, a type of scientific literacy. As early as 1888, one author (Dryer) saw the aim of science instruction:

...not to impart information, but to show pupils and parents that science is only exalted common sense, and deals with common things...scientific education is successful just so far as it creates in the mind the scientific spirit and the scientific habit... and produces a habit of mind which seeks for the cause of every consequence, refers all special phenomena to some general law, and from every set of conditions strives to calculate the inevitable result (pp. 208-209).

Other educators, such as Ballard (1888), Koyl (1888), Morrill (1888), Jordan (1890), Coulter (1893) and Westcott (1895) reiterated the idea of education producing scientific habits of mind and thought. David Starr Jordan (1896) said that the building of common sense was a function of the schools. He thought schools should help educated men distinguish science from "unscientific nonsense."

The work of the Committee of Ten pointed out the necessity of mental discipline as a goal of education. The summary report stated that "...every subject which they recommend can be made a serious subject of instruction, well fitted to train the pupil's powers of observation, expression, and reasoning" (NEA, p. 43).

The Geography conference summarized the ideas of other science conferences when they specifically addressed the issue of mental discipline. They suggested that it was important for teachers to identify mental processes to be gained from topics they taught. Teachers should approach each topic a particular way in order for students to receive the maximum mental training to be gotten from that topic. Students did not need to be informed of the theory behind the methods, but it was important that teachers know which mental faculty was being trained. The Geography conference suggested three classes of mental activities:

- (1) powers of observation
- (2) powers of scientific imagination and
- (3) powers of reasoning (NEA, 1893, p. 214).

These three mental activities served as a guide for teachers to sequence and arrange material for study. Teachers could "...definitely associate the topics they [were] endeavoring to teach with the mental powers they bring into exercise..." (p. 216). The justification of science as a means of exercising and developing mental faculties seemed to be an easy route. Justification on grounds of moral character was another story.

2. Moral Character:

Prior to 1895, there was a battle between education traditionalists and non-traditionalists about the inclusion of science courses in school curricula. Even though both groups realized that science courses provided a special kind of mental training, there was concern about science instruction providing for moral character development. For most educators, the aims of science education had to include an assimilation of the present day

pedagogical and psychological ideas, and the aims of scientific studies too. For many of them the chief end of education was the development of moral character (Shott, 1895). How to *fit* science instruction into the current framework seemed to be a dilemma. Could science instruction provide for moral character development?

In many cases, science as subject-matter, came under the same kind of attack as did psychology. W.T. Harris (1890) worried about the role of science instruction in elementary school curricula. He warned of dangers of relying too much on the "quality and quantity" characteristics of scientific processes. Harris recognized that quality and quantity measurements were two external means of observation which engaged scientists. External observation, he said, was in opposition to internal observation or introspection, and introspection was a means of providing evidence for the spiritual side of life.

Even though he hesitantly advocated the teaching of science courses in grammar and high schools (one hour per week), at the same time Harris concerned himself more with "the souls" of man. He defined nature as "the creation of souls" and he warned that the means of scientific study, in the use of external observation rather than introspection, had a non-spiritualizing tendency. Harris said, "While, therefore, we must acknowledge the importance of science-study in the elementary schools, we must not ignore its non spiritual tendency due to exaggerating the importance of inventorying external facts" (p.287).

He suggested that literary art, grammar, and especially history be used as corrective measures where science classes were taught. These subjects were "windows of the soul" and Harris saw these as having spiritualizing values and therefore able to easily "...counteract the narrowing tendencies of scientific instruction" (p. 287). Science study was not a "window of the soul" for Harris. It was a study called for in the new scientific society, but one that he saw must be approached with caution as far as concerned the soul of man.

Others also tried to reconcile and justify science instruction on the potential of its moral character development. Professor Shott of Carthage, Illinois (1895), much like W.T. Harris, arrived at the conclusion that science instruction needed tempering with instruction in history and literature. He suggested nature study could be approached through history and literature and that once interest in nature had carried the student forward in his studies, "...let us admit that the human characters in action and expression furnish the moral data and not the facts and laws of nature " (p. 169).

There were some who saw moralizing features of science. Since science study dealt with *truth* there could be no question of its moral character development (Yonce, 1888). People would give up superstition, custom, prejudice and comfort for truth. Science instruction could produce moral effects in students when their minds came into contact with that, that "never deceives; scientific truth" (Alling, 1881, p. 612). Brown (1896) said that science instruction made students susceptible to moral training as "...ignorance yields place to knowledge, fear to love, and cruelty to tenderness" (p.424). The philosophy of *science as truth* was a prevalent conception in the late-nineteenth century and one that justified its role in moral character development.

3. Educated vs. Instructed:

Under the two guiding principles of mental discipline and moral character development, what were other aims of late-nineteenth century science education? Were there other concerns besides disciplining the mind and developing moral character?

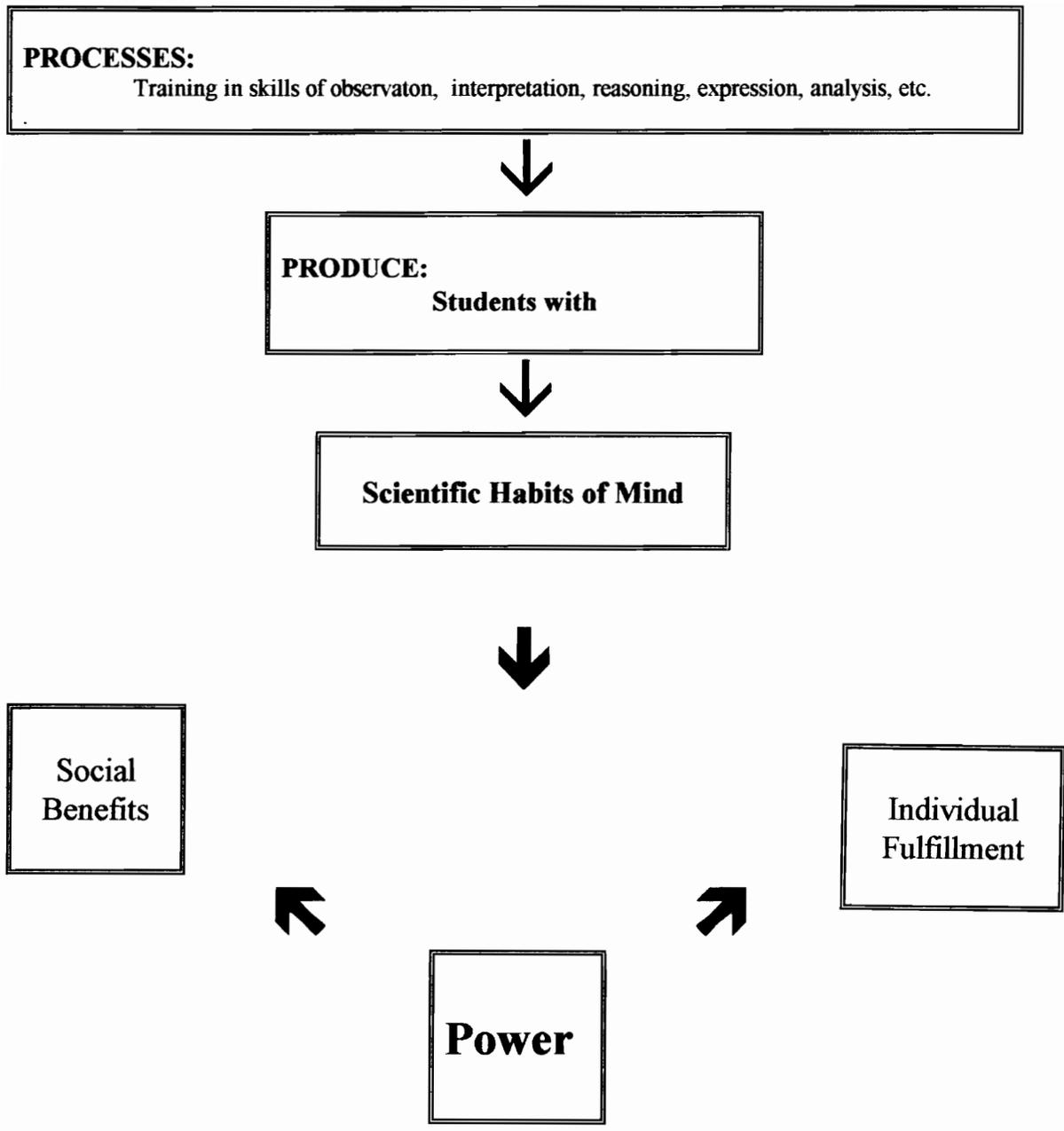
Some science educators (Morrison 1888; Westcott, 1895; Hay, 1898) pointed out differences between being educated as opposed to instructed. Whereas *instructed* had to do with knowing facts, being *educated* was equivalent to power. Educated implied more than knowing facts. It carried with it a meaning of knowing how to find out, how to

intelligently use what was found, and to rely on evidence and reason versus emotions in decision making situations.

"Knowledge is Power" appeared to be a slogan of the day. Scientific knowledge that was power, was that knowledge which prepared students for life. Even the Committee of Ten recognized the role of secondary schools as preparation for the "duties" of life. The secondary program developed by them for national use was for those whose education was not to go beyond secondary school as well as for those who did (NEA, 1893, p. 51).

An analysis of late-nineteenth century literature on science education reveals an overwhelming aim of educating for individual fulfillment, Figure 1. Educated individuals, trained in scientific habits of mind, were able to fully participate in a democratic society and thus, education benefited individuals and society at the same time (Alling, 1881; Dryer, 1888; Yonce, 1888).

The use of scientific processes provided individuals the power to deal with life. Training in observation, interpretation, and reasoning skills were the scientific processes sought for and many science educators believed that once individuals developed scientific habits of mind, they had the power to analyze, interpret and make final judgments based on evidence, Table 5. No longer would they be subject to superstitions and emotions. Scientific habits of mind required that final decisions be based on evidence. The glorious outcome of all this for students, as envisioned by late-nineteenth century science educators, was that they developed a desire for knowledge and truth and an interest in nature (Dryer, 1888; Ballard, 1888; Yonce, 1888; Clarke, 1889; Brown, 1896; Hay, 1898).



"To give the student power to enlarge his horizon; to see farther and more clearly into all sorts of things, to make his own and all lives better worth living..." (Dryer, 1888).

Figure 1: Aims of Late-Nineteenth Century Science Education --

Table 5: Late-Nineteenth Century Science Education Goals and Aims

Name	Goals and Aims	Name	Goals and Aims
1881 Alling	Right habits of thought and conduct; good citizenship.	1890 Jordan	To train the judgment through its exercise on first-hand knowledge.
1888 Dryer	To enlarge horizons; develop new faculties for own advantage and betterment of society; create scientific spirit and habit of mind.	1890 Guttenberg	Training in the observation of nature.
1888 Ballard	Train observation and discipline reason; develop love for truth; desire for knowledge; passion for research; fondness of investigation.	1891 Jackman	In lower grades to awaken powers of observation; in high school is the real teaching of the elements of science.
1888 Morrison	Make pupil willing and able to help himself to anything meets in life; responsibilities of life not through quantum of knowledge or instruction, but by will and power.	1892 Williams	Chief purpose is not knowledge, but the ability to gain knowledge, and therewith the ability and the disposition to be all one's life a learner.
1888 Koyl	Awaken interest; acquisition of scientific methods of thought and work; an acquaintance with facts of science and theories deduced from them.	1893 Coulter	To develop power, and to come into contact with the problems of life, and not to give information about plants and animals.
1888 Yonce	Awaken interest in natural phenomena; to initiate a habit which will reach all future studies; to dispel popular misapprehensions of common scientific truth; to show the uniform structure of matter; to mold character; to make more valuable citizens.	1895 Westcott	Facts are but secondary; biology should educate rather than instruct; to give power of observation, of discrimination, of delineation, of description ... Taught to investigate phenomena and facts and to draw logical inferences.-- Educated rather than instructed.
1888 Morrill	Taught how to study; to collect facts, classify them and draw conclusions. In a word to think.	1895 LeConte	Not merely to give useful information but rather to give the key with which the student may open and understand the book of nature.
1888 Zartman	To train the sense, the sight, the hearing, the taste, the smell, the touch -- to train the mind to interpret correctly the meanings derived from senses.	1896 Brown	Power to investigate, to overcome and use intelligently the forces of nature; power to master forms of language of which investigations of others are preserved; power to weigh motives and actions, to choose right, to reject wrong, to appreciate and enjoy the beautiful.
1889 Clarke	To awaken and guide the curiosity of the child to natural phenomena	1898 Hay	Principal aim of high school biology is to educate, to instruct, and to foster a love of nature.
1889 Allen	Constant training of the senses to cultivate other faculties of judgment, discrimination, comparison, and arrangement. To form hypotheses and to test them, to detect and eliminate errors, to apply suitable means of verification, to learn to suspend judgment in cases of real doubt and to decide on true analogy.	1899 Editor's Table <i>Popular Science Monthly</i>	Imparts true ideas in regard to the physical history of the globe and the chemical elements that comprise it, but aims no less at unfolding the true constitution of society, the springs of human action, the strength and weakness of human character, the possibilities of good and evil that reside in every individual, the misery that awaits on wrongdoing and the happiness that follows from just and pure deeds.

A major instructional emphasis to accomplish the goal of personal empowerment and social betterment in the late-nineteenth century, was belief in the laboratory method of instruction to develop faculties of observation and reasoning. The various science conferences of the Committee of Ten supported this idea. The Physics, Chemistry and Astronomy Conferences stated that the major goal of science instruction was the training of students' faculties to make accurate observations and draw inferences from those observations. This training occurred mainly through laboratory work. Observing natural phenomena, recording data clearly and precisely, analyzing data, and inductively arriving at conclusions based on observable data were primary processes of science that benefited students in later life. Late-nineteenth century science educators believed that science courses were practical in that the skills obtained in the laboratory could be used in everyday life for reasoning and making judgments (Morrison, 1888; Coulter, 1893; Brown, 1896; Paddock, 1896).

Other less often cited aims of science instruction had to do with science as information. A few authors (Koyle, 1888; Yonce, 1888; Carhart, 1896; Hay, 1898) mentioned an aim of science instruction for factual knowledge, but this was usually not the most important aim stated. Aims such as dispelling misapprehensions about scientific knowledge (Dryer, 1888; Yonce, 1888; Westcott, 1895), and science courses taught to meet admission requirements for college (Rappleye, 1897), were minor as compared to the four aims identified from the periodical literature by this author and summarized in Table 6.

The primary aim of late-nineteenth century science instruction was to develop personal faculties of observation, expression, reasoning, etc. These faculties gave students power to deal with whatever they encountered in life. The key to training students in scientific habits of mind lay in the use of laboratory methods of instruction. As a newly

Table 6: Most Commonly Cited Goals and Aims of Late-Nineteenth Century Science Education

<p>1. Education of the individual for personal fulfillment and the betterment of society. To mold character and produce good citizens.</p>
<p>2. Education for empowerment -- Power for the individual to deal with situations that arise in daily life. Power comes from training in scientific skills, such as observing, interpreting, reasoning, classifying and decision making.</p>
<p>3. Education for the development of scientific habits of mind.</p>
<p>4. Education to awaken interest in science and to become acquainted with some of the facts of science. To develop a love of study and knowledge.</p>

suggested or recommended type of instructional process in science, the laboratory method exemplified the hopes of science educational reformers (Lewis, 1887; Rappleye, 1887; Dryer, 1888; Ballard, 1888; Morrison, 1888; Koyl, 1888; Morrill, 1888; Zartman, 1888; Allen, 1889; Jordan, 1890; Jackman, 1895; LeConte, 1895; Boyer, 1897; Hay, 1898).

IV. The Laboratory Method

1. Baconianism of School Science:

Credit goes to Francis Bacon with beginning the idea of experimental science in the seventeenth century. The new experimental philosophy of Bacon contrasted with the Aristotelian view of science as an observational and logical mental process. Whereas Aristotle based his scientific truths on deductive logic, Bacon advocated an inductive approach. Aristotle developed syllogisms as a means of deducing truth from observations, while Bacon promoted verification of scientific truth from observation and experimentation.

Bacon believed that inductive generalizations, based upon experimentally collected facts, revealed the true nature of Nature. For Bacon, science was more than an appreciation of natural history, more than practical knowledge, more than an intellectual system for understanding man's place in nature, more than a revelation of a divine plan for the world, but "[i]t was also a *work* that could be done to change the world for the better" (Prather, 1992, p.284). Followers of Bacon exalted in performing experiments and

collecting facts.* Baconians believed that there existed an ultimate truth that man could discover through empirical and inductive processes.

Two hundred years later, Baconianism still ruled and played a large part in the philosophy behind the institution of instructional methods in science education. Perkinson (1984) attributed the *transmission mode* of instruction to Bacon. Bacon's ideas of learning through experiences and inductively reaching generalizations, established teachers as *transmitters*, based on their greater degree of experiences. Students, based on their lack of experiences, became *learners*. This led to teacher-centered instruction as opposed to child-centered instruction for which reformers of the late-nineteenth century began to call (p.16).

The philosophical ideas behind Bacon's experimental science is seen in late-nineteenth century school science. Instructional methods used to develop process skills were experimentation and laboratory work. Science educators believed that through careful and accurate observations of nature, man (students) could arrive at or discover the "ultimate truth" (Skinner, 1897).

W.T. Harris (1890) best described the philosophy of late-nineteenth century science when he said, "...man in fact conquers nature; by learning Nature's storehouses and the laws of natural forces, man can harness those forces, set them to work, to produce food, clothing, and shelter" (p. 277). This illustrates the true Baconian quality of science evident in this period, science that was conquerable by man to reveal the ultimate truth.

The role of the laboratory as explained by Servos (1986), a historian of science, sheds some light on one reason why late-nineteenth century educators were so insistent

* Although Bacon idealized the experimental method, he only once performed an experiment of his own - and this resulted in his death. Bacon succumbed to pneumonia after experimenting with freezing a chicken in the snow. It is noted however, that other experimenters met with more favorable success!

upon laboratory instruction. Servos stated that Baconianism survived and prospered in America because it corresponded with values of American scientists. He suggested that scientists viewed the "special mystique" of the laboratory as more than training scientists or producing new knowledge.

For many of them the laboratory was, first and foremost, a place to mold character, to inculcate in the young men the virtues of honesty, perseverance, and fidelity in the little things, and to instill respect for painstaking manual labor. Value inhered not just in the product, but also in the process of laboratory work, and such research fit easily into the moral universe of Victorian America (p. 614).

The laboratory method of instruction supported the educational aim of developing moral character and provided training in scientific processes. It was therefore a vital part of the science instructional process.

2. Laboratory Instruction in Schools:

A. Secondary Schools:

In the various science conference reports of the Committee of Ten, one word that appears most often in the discussion of the laboratory method is *observation*. Observing nature first hand seemed to be the overwhelming instructional process suggested for science classes. In biology especially, observation and drawing were of particular importance (Westcott, 1895). In the case of most experimental situations, such as would occur in physics and chemistry, experiments illustrated or demonstrated scientific laws and principles.

The laboratory approach to teaching science was *the new* instructional method of late-nineteenth century science. All the conferences of the Committee of Ten were adamant that science teaching occur through laboratory methods. They recommended the laboratory method as the *best* method of instruction from primary through secondary grades. Other late-nineteenth century educators concurred, Table 7.

Science educators worried over the *correct* use of laboratory methods in schools. Members of the science conferences of the Committee of Ten realized that laboratory methods required expertise on the part of teachers. Laboratory instruction could fall prey to the unprepared and result in little benefit for students. As early as 1885, one writer (Martin) recognized that just because laboratory work involved students in processes of performing experiments and "looking with their eyes" they did not necessarily learn chemistry (p. 471). Textbook experiments often led students to get their answers from the book.

A couple of authors (Morrill, 1888; Ballard, 1888) were leery of the entertainment qualities of the laboratory. They saw that experiments could easily fall into the role of awing or amusing students rather than providing educational benefits. Morrill (1888) warned that the "old idea of experiments was...to amuse." He cited laboratory objects that he referred to as playthings, like "pneumatic and electrical" apparatus (pp. 409-410). However, most science educators glorified the use of the laboratory method--so much so to the extent that if you could not teach science by experimentation and hands-on methods, one author (Nelson 1893) suggested that it was better not to teach it at all.

The biologist Ward (1897) described laboratory work as the "keystone of the modern scientific method" (p. 953). Laboratory work was to involve students for the major part of class time; Ward suggested that 3/5 to 3/4 of the time allotted for science

Table 7: The Role of the Laboratory in Late-Nineteenth Century Science Education

Name	Role of Lab	Name	Role of Lab
1885 Martin	To illustrate & demonstrate laws	1895 Harris	To illustrate principles and events
1888 Morrison	To develop powers; to demonstrate chemical laws	1896 Skinner	To lead pupils to discover the ultimate truth
1888 Morrill	To illustrate fundamental principles	1897 Cornish	To discover or verify laws; to arouse interest and lead student to think and work
1888 Zartman	To illustrate descriptive chemistry with quantitative work	1897 Ward	Keystone of modern scientific method; work should be logical; quality not quantity yields results sought for
1895 Westcott	In biology lab students taught to see accurately, hear accurately, draw accurately, talk accurately, and write accurately	1899 Richardson	To illustrate some principle or some important property of the thing under consideration

should be in the laboratory. Laboratory work actively involved students in observing, drawing, record keeping, and comparison of observations in order to reach generalizations (p. 954).

Four logical steps of laboratory work identified by Ward (1897) sum up the processes involved in late-nineteenth century schools.

- (1) *Observation* was the most important process. It was in this process that students learned to distinguish "...what is actually observed and what is only an inference from the facts observed."
- (2) *Drawing* succeeded observations for drawing was a means of reproducing what was seen. This helped to establish a knowledge of facts.
- (3) Accurate *record keeping* was all important in scientific areas. Ward recommended that the laboratory manual or notebook follow a student through school and be accepted as part of college admission requirements.
- (4) The last step in the laboratory process was comparison of observations with other cases. Comparison involved the processes of *induction and generalization*. Inductive science was the mainstay of the late-nineteenth century, Figure 2.

Members of the science conferences of the Committee of Ten saw laboratory experiences as so important that they recommended high school lab notebooks and a practical laboratory test be part of college admission.* The laboratory notebook was a highly valued commodity. Teachers emphasized the incorporation of good writing skills, and neat and accurate work as an important part of good laboratory record keeping.

* Harvard University in 1887 issued a descriptive list of experiments required for admission (Morrill, 1888, p. 410).

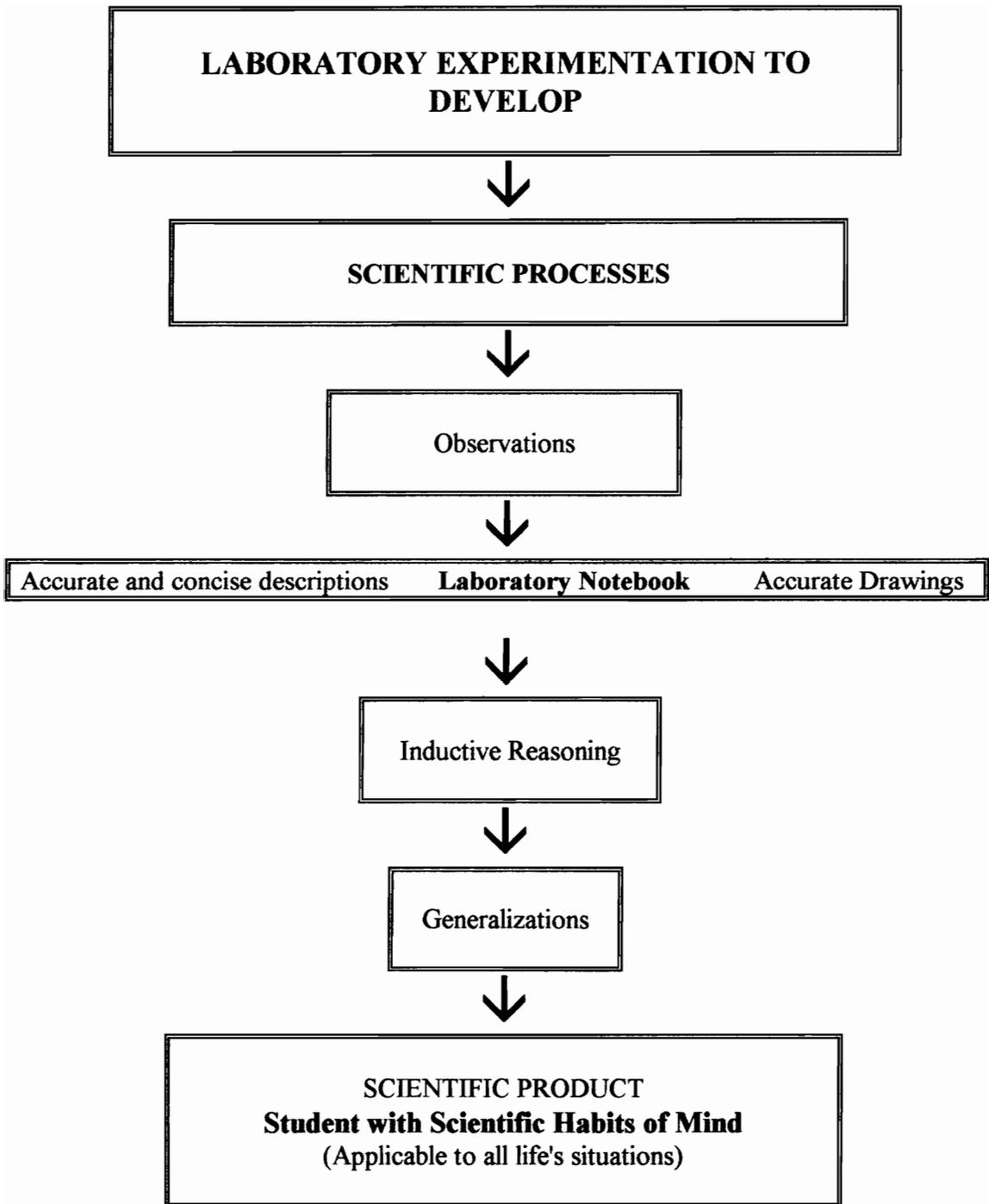


Figure 2: Role of the Laboratory in Late-Nineteenth Century Science Education

Descriptions of science classrooms in secondary schools showed an abundance of students, in some cases as many as 50-130. In 1888, the science teacher Morrison described his physics and chemistry classes. This description was typical of many schools trying to establish laboratory sciences. Morrison's physics class contained 130 pupils, and only one set of apparatus. Because of this, only one student or one set of students actually performed the experiment while others observed, asked questions and took notes (p. 273). Morrison had 96 pupils in his chemistry class. In order to facilitate laboratory work in chemistry, he divided his class into three sections (32 each), for a one hour recitation period each. Each of these sections he then divided into two divisions (16 each). The laboratory could hold 16 pupils at a time, so while 16 pupils were involved in recitation, 16 others were in the laboratory.

After he had given the whole section rules and preliminary instructions the day before, Morrison sent one division of students to the lab. "They are sent into the laboratory alone even on the first day. Encouraged by finding themselves thrown on their own resources, and on their honor...they are pleased with newly discovered power and are always eager for the next day's exercise" (p. 277-278). Morrison remained in the classroom to hear recitations of the remaining students. The next day, the divisions switched places and in the recitation room, students were "...held to strict account for work done in the laboratory and instructed how to keep a neat and complete record of what they [performed] (p. 278). Therefore, experiments were often carried out by students in the absence of teacher guidance.*

* This points out one area not discussed in this study -- safety! Safety concerns today would not permit such a situation to occur. Today all 32 students would perform experiments at the same time! Whereas the late-nineteenth century was inhibited by lack of equipment and too many students, today safety precautions and waste disposal impose restrictions on laboratory practices and experiments in high schools.

B. Elementary Schools:

In grades below high school, the laboratory method was also the keystone to science education. Normal school teacher Wilbur Jackman (1895) wrote that as far as concerned reforming the primary and grammar schools, it was the study of nature that played the leading role. "Its [nature study] strength at present lies chiefly in its fulfillment of the public demand for that work which will acquaint the pupil with the conditions of modern life..." (p. 98).

Like in secondary schools, the process of observation played a big role in elementary school science. Educators believed observation established an interest in nature. Guttenberg (1890) was a science educator who called for observations of nature as a necessary part of elementary school science. He stated that pupils involved in observing should investigate things that were concrete and known to them. At all cost, Guttenberg warned teachers to avoid technical terms.

Guttenberg, along with others (Jackman, 1895, Clapp 1895, Rice 1895a), called for a correlation of studies at the elementary level. This involved investigating nature and using these investigations in the study of other established subjects as well. In this way, science classes did not become isolated entities, but became part of the total school curriculum.

Francis Parker and Wilbur Jackman became the major proponents of this type of nature study in grammar grades. At the Cook County Normal School, where both Parker and Jackman taught, they organized the total curriculum with nature study surrounding the child. All other subjects, language, composition, history, math and drawing correlated to the work done in nature study, Figure 3. This was Francis Parker's "Theory of Concentration" (Parker, 1894, p. ii). Jackman also prepared a lesson guide for teachers using correlation and nature study as guides, Figure 4.

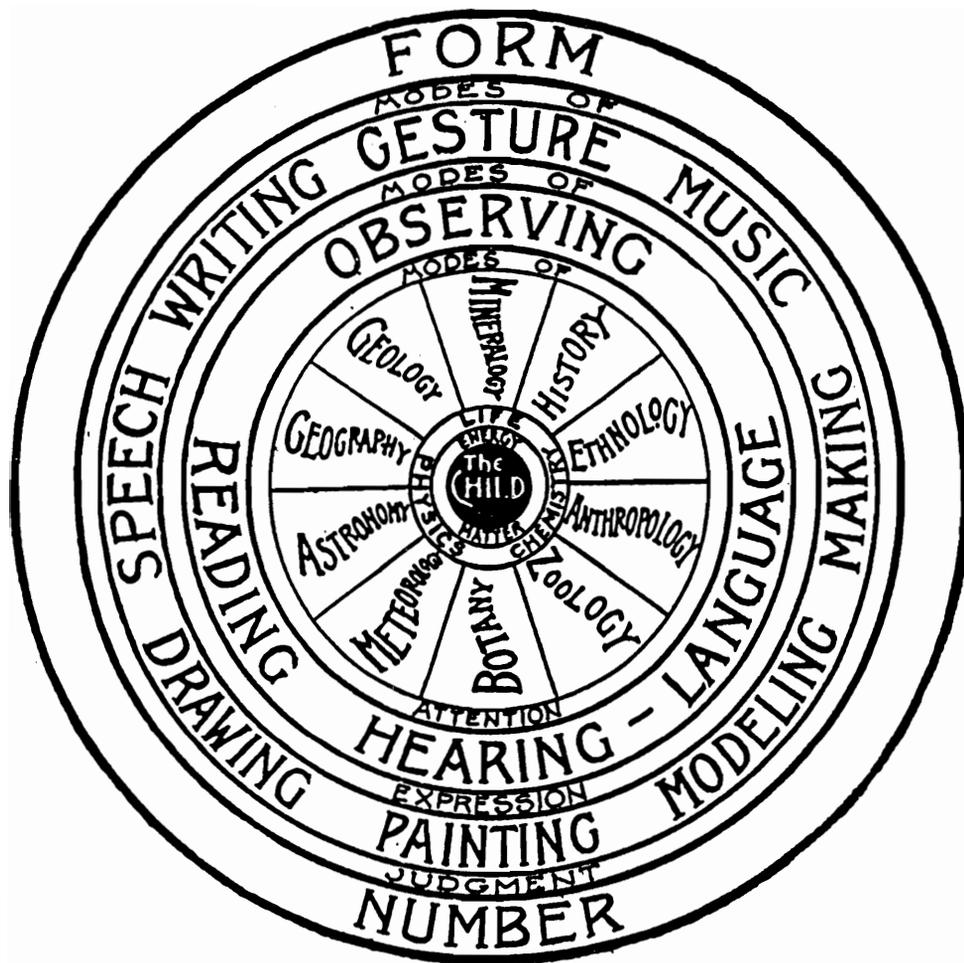


Figure 3: Chart Illustrating the Theory of Concentration; from *Talks On Pedagogy*,
by Francis W. Parker, 1894, p. i.

I. PLAN FOR EACH LESSON

A. *Knowledge of subject matter.*

1. By direct observation

- a. What can be seen in a field-lesson?
- b. What can be collected by individual pupils?
- c. What can the pupils make?

2. What reading belongs legitimately to the preparation?

3. The adaptation to the pupils' and teachers' conditions.

4. The adaptation to the age and capabilities of the pupils, i.e., to grade.

5. What is the length of time which should be devoted to the preparation of the lesson?

B. *What modes of expression should be used?*

1. Oral language?

2. Written language?

}What suggestive reading?

3. Painting.

4. Modeling.

5. Drawing.

6. Making.

C. *How is the lesson related to other subjects?*

1. Reading.

2. Number.

3. History and literature.

4. Language.

II. HINTS TO BE OBSERVED IN GIVING THE LESSON?

1. Have a reason clearly in mind for giving every lesson. *Seek for this in the relation of the subject to the child.*

2. Have a reason clearly in mind for the way in which the lesson is presented. *Seek for this in a study of the laws which govern the growth of the child's mind.*

3. Plan only for such work as the pupils can do for themselves, or at least, take the leading part in doing.

4. Place the child directly in contact with nature *under normal conditions.*

5. Begin with something which is really a part of the pupil's experience -- not *with something which you have to tell him.*

6. Accept, as good, only such results as indicate honesty of purpose and growth of mind.

7. Be faithful, and bide your time.

Figure 4: Guide for Preparation of Lessons in Nature Study; Jackman, 1894

Because all nature study dealt with things known to students, science in the primary and grammar grades was clearly student-centered. Clapp (1893), Master at George Putnam School in Boston, Mass., saw the child's natural methods of working as the basis of instruction in elementary science. He suggested that in the elementary grades, science instruction must always occur from the interests of students. How students worked, what they worked on, and how best they expressed their ideas was to be the basis of elementary science, according to Clapp. The best means of doing this was to allow students to work with the *thing* itself. Observation, examination, drawing, and describing in writing were the science of the child. Jackman(1894) said "...the child stands at the center of the universe..." in science instruction. Elementary teachers adapted their science instruction to the natural conditions of pupils.

The laboratory method almost had a magical quality about it for science educators, no matter what grade level. They believed that facts and laws of science became "matters of immediate knowledge" if observed in the laboratory (Cornish, 1897). They also believed that work in the laboratory instilled scientific habits of mind necessary for life.

V. Late-Nineteenth Century Professional Educators

Servos described the 1870s and 1880s as a time when many American scientists "...defined themselves as professional educators rather than as professional physicists or chemists." This could be true of many of the late-nineteenth century science educators that appear in this study (Table 7). Most ideas of reformation in science instruction were coming from college science professors, college presidents, high school principals or normal school teachers (Tables 3 & 4). Even though educated in specific science

disciplines, many of these educators concerned themselves with instructional problems of science at the college, high school and grammar school levels. Their publications appeared in journals such as *Education*, *The School Review* and *Popular Science Monthly*.

Few high school teachers seemed to be involved in the reform movement. Of course, one factor for their omission could have been the poor quality of preparation of high school science teachers. Rice (1895b) said that the greatest fault of schools was the weakness of teachers. He said that the lack was not in "desire," but "...in the lack of the required knowledge and skill to properly apply recognized principles in teaching" (p. 681).

1. Teachers:

At Lexington Green, Massachusetts, in 1839, Horace Mann, secretary of the State Board of Education, established the first normal school (Mayo, 1887). Normal schools were schools that specialized in the education and preparation of teachers. All subjects were approached with pedagogical ideas needed by classroom teachers. Normal schools helped provide teachers for the growing school systems of the nation. Educators recognized that teachers needed training in pedagogical aspects of education as well as in subject matter material.

As the number of pupils greatly increased in public schools during the late decades of the 1800s, school systems struggled to find teachers to fill the numerous positions. Mayo (1887) stated that in 1847, Massachusetts had fourteen high schools, but forty years later there were two hundred twenty four high schools. This was a situation common in many urban areas and school systems hired many unskilled teachers to fill teaching positions available as a result of the sudden increase in school attendance. Educator Greenwood (1889) said, "A stringent law requiring all teachers of any one state to be

thoroughly qualified to teach, would reduce the teaching force of that state at least by sixty per cent" (p. 306).

There was a public outcry for more and better prepared teachers. Normal schools became a solution to the problem. The historian Swett (1900) cited 164 as the total number of normal schools, both state and municipal public normal schools, in 1896-97. The total enrollment he put at 43,197 students, with the number of graduates from public normal schools at 8,032. Of these 62.6% were women (p. 79).

In courses that lasted two to three, and in some cases, four years, normal school students covered all the "subjects of the common school" as well as the "theory and art of teaching" (Smith, 1882, p. 381). Smith, a normal school teacher, lauded the advancements brought about by normal schools. She cited improvements in teaching reading with the new "word-method" of instruction. Arithmetic instruction improved as it was taught through concrete not abstract ideas. Advancements in the area of observation involved the use of forms and colors, weaving, drawing and modeling. Other improvements were in the use of nature study, oral lessons by the teacher, an increased atmosphere of love, textbooks with pictures and an easy style, and improvements in discipline (p. 380). Although Smith applauded the progress made in teaching, and attributed this to the normal school, she saw the "...greatest proportion of our schools still in the gripe [*sic*] of empiricism and the bonds of tradition" (p. 381).

Several educators (Smith, 1882; Greenwood, 1889; Parsons, 1890; Schurman, 1896) supplied statistics on teachers and normal schools of the late-nineteenth century. Smith (1882), a normal school teacher in Washington, D.C., said that less than four percent of all teachers required annually were normal school graduates. This could be a very small number of teachers because educator Greenwood (1889) said that in some states as many as forty percent of the teachers quit every year. He set the average

teaching time at about three years, whereas Schurman (1896), seven years later, wrote that the average professional career was between seven and eight years.

In describing the typical normal school student in Indiana, educator Parsons (1890) stated that the average age was greater than twenty-two. He reported that twenty-two percent of the students were graduates of high school or academies, ten percent had one to two years of high school, while sixty to sixty-five percent came from district schools or city graded schools. About one-half of the students in attendance were already teachers.

There were two types of courses of study at most normal schools. There were the academic and professional ways of studying a subject. Normal school students studied such things as botany, arithmetic, history, literature, geometry, "...not for self-culture, but to acquire such knowledge of the subject as will enable one to wield it as an instrument in the education of others....He is acquiring a teacher's knowledge of the subject" (Parsons, 1890, p. 720, 721). Education in the normal school intertwined subject matter along with pedagogical aspects of the subject.

Parsons suggested that normal school education should be five years. He said that if a young man had the choice between four years of college and one year afterwards in professional training or five years in a normal school, that he (Parsons) thinks the best choice would be five years of normal school -- all other factors being equal. He gave five reasons for this:

- (1) Normal schools put emphasis and stress on the organization of the subject.
- (2) In the normal school, every subject is to be taught as an illustration and exemplification of the doctrines of education and method.

- (3) To study an academic subject in the atmosphere created by the presence of a large number of persons pursuing the same end, is itself a reinforcement of the individual's own power.
- (4) In normal school the student puts himself into the attitude of the teacher while studying a given subject --assumes a teacher's mental attitude.
- (5) The strongest reason given was that -- conditions exist for the analysis and study of the mental processes employed in mastering them [academic subjects] (p. 723).

By the late 1890s and the early years of the 1900s, the opinion of the normal schools changed in the literature. Whereas earlier literature (Smith, 1882; Mayo, 1887) praised the work done by normal schools, other educators (Schurman, 1896; Aspenwall, 1902; Abernethy, 1903) began to question that perception. These authors began to see the need for more and better education of teachers. They began to envision the professional teacher-educator in colleges and universities.

The educator Schurman (1896) said that teachers always needed four more years of schooling than the pupils they taught. Therefore, teachers of elementary schools must have completed high school, while those who taught in the high schools, academies, and normal schools should be college graduates. He cited the fact that only fifteen percent of all teachers in the United States had passed normal school.

Schurman suggested that in the education of secondary teachers at the college level, they should "...devote at least one-half time to subjects he proposes to teach" (p. 181). He saw normal school education as appropriate for primary teachers, but not for the college graduate who wished to teach. Schurman said normal schools were "...designed for pupils of much less intellectual maturity and culture" (p. 181). He suggested and predicted that

there should and would be training colleges among the professional schools of the university. He predicted that someday there would be a "...graduate school of pedagogy" (p.184).

In 1902, the educator Aspenwall named colleges and universities that had instituted professional education classes -- Harvard, Columbia, the University of Michigan, and the University of Chicago. Science educator Abernethy (1903) mentioned Cornell with a professorship of the "Science and Art of Education," the University of Rochester with its "Teachers' Training Department," Middleburg College that had a "senior year course in pedagogy and methods of teaching," and the Woman's College in Brown University that offered teaching courses and student-teaching in connection with the city of Providence (p. 327). The normal school appeared to be on its way out. Abernethy unrelentingly applauded this passing. "The old fashion normal school is on the road to oblivion, and every earnest educator wishes for it a speedy end of the journey" (p. 325).

From this description of normal schools and teachers, the poor quality of science teachers that other educators (Cutting, 1887; Lewis, 1887; Rappleye, 1887; Dryer, 1888; Jordan 1890) mentioned in the literature appeared to be a very real situation. The fact that science was not a subject taught in many public schools, and to a small extent in colleges, reveals that the poor quality of science teachers appeared to be even more likely than in other areas of instruction. So, when late-nineteenth century educators reported the scarcity of good science teachers, it is easy to believe the problem was real based on the poor educational background of teachers in general. "As is the teacher, so is the school," was a maxim quoted by several authors (Smith, 1882; Bradley, 1888).

2. Other Influential Educators:

Professional educators who influenced late-nineteenth century schools were people such as those in the Committee of Ten membership (Table 3), in the science conferences (Table 4) and some of those science educators encountered in this study and listed in Table 8. The majority of these people were college or normal school teachers, college presidents or principals and headmasters. In the science conferences of the Committee of Ten, 17 of the 30 members were from normal schools, colleges and universities. The remaining 13 members were mainly high school principals, headmasters or superintendents. Krug (1964) wrote "Here was the opportunity for academic scholars, associated with practical school men, to make their mark on the school subjects" (p. 53).

There was one member of the Committee of Ten that stands out as being very influential on science instruction in high schools. This was Charles W. Eliot. As chairman of the Committee of Ten, he exerted a great deal of influence on the make-up and direction of the Committee. The goal, as far as Eliot was concerned, for the Committee of Ten was not uniform offerings or uniform programs for pupils, but "[r]ather it was uniformity of topics, methods, and standards of attainment for any subjects that might be offered or taken (Krug, 1964, p.46). One of these uniform methods was the laboratory method of instruction in science classrooms.

Charles W. Eliot Herbert Spencer and Thomas Huxley influenced the ideas of Charles Eliot. Through Eliot's role as an innovative educator, his position as President of Harvard, and very importantly for secondary science, as chairman of the Committee of Ten, he pushed for the teaching of laboratory sciences in schools. His strong beliefs in learning science by observation and inductive processes had tremendous impact on science instruction in the late 1890s.

Table 8: Names and Positions of Some Late-Nineteenth Century Science Educators

Name	Position	Name	Position
Brown, Elizabeth .	Normal School, Washington, D.C.	Koyl, C.H.	Swarthmore, Pa.
Ballard, H.H.	Pittsfield, Mass.	Macmillan, C.	U. Minnesota
Bessey, C.E.	Prof. U. Neb.	Martin, L.J.	H.S. Indianapolis, Ind.
Boyden, A.C.	Bridgewater Normal School, Mass.	Meads, S.P.	Head Sc. Dept. Oakland H.S., Oakland, Calif.
Brigham, A.P.	Prof. Geology - Colgate	Morrill, A.D.	Athens, Ohio
Bryan, W.L.	Prof. U. Ind.	Morrison, G.B.	Kansas City H. S.
Cobb, C.N.	U. of the State of N.Y.	Mowry, A.M.	H.S. Gloucester, Mass
Carhart, H.S.	U. Michigan	Nelson, A.	U. Wyoming
Clapp, H.L.	Master - George Putnam School, Boston	Palmer, C.S.	U. Colorado
Coulter, J.M.	Prof. Bio.	Parker, F.W.	Cook Co. Normal School
Cook, W.	U. Michigan	Rappleye, W.G.	Oswego Normal Sch
Cornish, R.H.	Morgan Park Academy, Morgan Park, Ill.	Richardson, G.M.	Prof. chem. -Leland Stanford Jr. Coll
Dryer, C.R.	Ind. Normal School	Shott, J.A.	Prof. Carthage, Ill
Frost, S.T.	Headmaster - High School, Meriden, Conn.	Schooling, W.	
Freer, P.C.	U. Michigan	Skinner, W.H.	Nebraska City, Neb.
Guttenberg, G.	Pittsburg, Pa.	Ward, H.B.	U. Nebraska
Gage, S.H.	English High School Boston	Weed, C.M.	Prof. New Hampshire Coll, Durhan, N.H.
Harris, E.L.	Prin. Central H.S. Cleveland, Ohio	Waldo, F.	Ph.D. Cambridge, Mass
Harris, W.T.	Commissioner of Ed.	Westcott, O.S.	Prin. North Div. H. S. Chicago, Ill.
Harvey, N. A.	State Normal School West Superior, Wis.	Williams, S.G.	Cornell University
Henderson, C.H.	Prin. NE Manual Training School, Philadelphia	Wilson, L.L.W.	Chair Bio. Dept. Phil. Normal Sch
Jackman, W.S.	Cook Co. Normal School	Yonce. G.V.	Lutherville Sem. Maryland
Jordan, D.S.	Pres. Ind. U. and late Leland-Stanford College	Zartman, G.E.	Waterloo, N.Y.

After graduating from Harvard in 1853, Eliot became a tutor in mathematics there in 1854 and assistant professor in mathematics and chemistry from 1858-1863. In 1861 Eliot became head of the Lawrence Scientific School and was in charge of the Chemistry Department. Sizer (1964), an educational historian, says that "...failing to be appointed to the coveted Rumford chair, he resigned in disappointment" (p. 78). During the next two years he studied chemistry and pedagogy in Europe.

Upon his return from Europe, he became a faculty member at Massachusetts Institute of Technology in analytical chemistry. In this position Eliot introduced a course in instruction of laboratory methods for teachers of chemistry, for both men and women (James, 1930, p. 161). A letter of 1867 relates some of his views about how chemistry should be taught; "Discouragement of the memoretic teaching of chemistry which prevails, and the substitution thereof of experimenting before, and better by, the pupils (James, 1930, p. 163).

In 1869, Eliot became President of Harvard University. With his push for more electives in the college curriculum, Harvard became one of the earliest colleges to recognize natural science for college entrance. Henry James in his 1930 biography of Eliot stated:

American history, English literature, and science have at last become staples of our school curricula....Teaching now tries not to be authoritative, pays more attention to the pupil's faculties of observation and decision, and tries harder to enlist his initiative....The reforms of the last half-century were, of course, not of Eliot's sole making any more than the immense tide of universal transmutation was of his raising. But on point after point his voice

was one of the first and one of the clearest that urged and prophesied change (p. 366).

One governing psychological theory that influenced Eliot's reformation ideas in education was that of mental faculties. Whereas many educators of the time considered only the study of classical languages as developers of mental faculties, Eliot perceived that other subjects could play the same role. In his article, "Some Failures of Popular Education," of December, 1892, Eliot specified "...those main processes or operations of the mind which systematic education should develop and improve in an individual in order to increase his general intelligence and train his reasoning power" (Krug, 1961, p. 68). He presented four of these processes:

- (1) observation -- alert, intent, and accurate use of all the senses
- (2) making correct record of things observed, either mentally or written in a notebook
- (3) drawing correct inferences from recorded observations -- developed by practice in induction and
- (4) expressing one's thoughts clearly, concisely, and cogently (Krug, 1961).

Eliot referred to education in general as needing these four processes, the scientific processes of observing, recording, making inferences inductively, and reporting the results. In this list of "operations of the mind," Spencer's influence is seen. He too advocated skills needed for life; skills of observing, interpreting, and reasoning. Of course, Eliot's background in science could account for many of his views on processes of the mind that science education should develop.

Eliot thought that strengthening of reasoning powers must be the constant object of all teaching, from infancy to adult age, "...no matter what may be the subject of instruction" (Krug, 1961, p. 78). However, instruction in the natural sciences was to occur through the senses. Things, not books, were the source of knowledge for the natural sciences. Yet, specific scientific knowledge was not his ultimate goal for the public high school science curriculum. Eliot had no particular objection to imparting of some information in secondary schools, provided of course, it did not interfere with training. He denounced as "mischievous delusions," ideas that high school graduates must "know something about" this or that science. If a pupil studied science, what he should get from his study was "...training in the power to observe accurately, describe correctly, and reason justly"...in fact this is what he should get from any subject well taught (Krug, 1964, p.204-205).

Eliot's pedagogical beliefs naturally led to laboratory methods of teaching science. Sizer (1964) depicted Eliot as a scientist, as one who "...reflected the mood of science, interpreted it, and translated it into action....Eliot was a devotee of no one, but rather a man caught in the stream of science and the new intellectual currents of his day" (p. 78).

VI. Summary

In times of great scientific and technological achievements, educators of the late-nineteenth century recognized a need for new and different kinds of courses in secondary schools. Late-nineteenth century reformers pushed for the establishment of laboratory science courses in the public schools, a job at which they began to succeed. Based on curricula suggestions and the authority provided by the report of the Committee of Ten,

science educators initiated science courses into a reformed secondary curricula. Botany, zoology, astronomy, physics, chemistry, geography and physiology became the main science courses taught in secondary schools.

To science reformers, students' personal fulfillment in education depended upon the incorporation of scientific processes into students' habits of thought. Reformers hoped for science courses which would prepare students to participate in the scientific and technological society of their times. Science educators wanted citizens to use their knowledge of scientific processes to guide them in decision making processes. Science educators hoped that emotional decision-making processes could be overcome through careful analyses and judgments based on the use of processes of science. The scientific spirit and habit of mind, in the reformers' ideals, would lead to competent citizens and a better democratic society.

Late-nineteenth century reformers perceived the laboratory method of instruction as the ideal method by which science courses should be taught. At the secondary level reformers envisioned the use of this instructional method as the focus of all science study, while at the elementary level, the child's interests in surrounding nature and natural phenomena guided science study.

The incorporation of these methods required well prepared science teachers, an element that appeared to be missing in late-nineteenth century schools. All reformers realized the need for better teacher preparation programs and suggested college and university preparation for all teachers, as opposed to a normal school education. As the nineteenth century was ending, recommendations were underway to provide teacher training in many universities and colleges.

These were some of the hopes and visions of late-nineteenth century science education reformers, but with all of these great visions, dreams and recommendations as

guides to reform science instruction, science classes at the end of the nineteenth century appeared to be of much lower quality than educators hoped for in the schools. As the author has shown, rote memorization, recitation and lack of experience with nature and natural phenomena were most often the reality of the classroom, but all the efforts of late-nineteenth century science education reformers were not in vain. They laid the foundations for the inclusion of science courses in secondary schools and established instructional ideals that influenced reformers throughout the decades to follow.

CHAPTER 3

FACTORS ASSOCIATED WITH AND INFLUENTIAL ON REFORM PROCESSES OF LATE-TWENTIETH CENTURY SCIENCE EDUCATION

I. The Times

By and large, the popular view of science remains much the same as that arrived at a century ago. That science is a powerful and progressive path to certain knowledge has been underscored by the proliferation of technology and of high technology, and especially the harnessing of atomic energy in the 1940s (Bauer, 1992, p. 34).

1. Technology, Economics, and International Testing:

There is a technological revolution occurring today. The technological revolution is not in industrial processes, as in the late-nineteenth century, but rather in communication, information, and fact gathering processes. Much of this revolution stems from new technological uses of the silicon chip. The development and use of the silicon chip has brought about enormous changes within the past two decades. Silicon chips in computers, cars, microwave ovens, telephones, satellites, TV's, etc., do for today's society what industry did in the late-nineteenth century. Gadgets abound.

One result of the influx of the silicon chip into society is the vast amount of information that is now accessible through computers. Computers jetted the 1980s and 1990s into an age of facts and statistics. Perkinson (1991) stated that the computer's

ability to handle facts and information, as statistics, had great impact on society. "Suddenly, statistics were everywhere; the world was being mathematicized" (p. 286). This mathematization included the world of science education.

Facts and statistics gathered from international tests of scientific knowledge and analysis of our own science curricula seem to reveal that American schools do not provide the type of science education necessary for success in modern society. In the 1990-1991 International Assessment of Educational Progress, thirteen year-olds in the United States ranked 13th in tests of scientific knowledge. Countries such as Korea, Taiwan, Switzerland, Hungary, Soviet Union, Slovenia, Italy, Israel, Canada, France, Scotland, and Spain outscored the United States in this assessment, Figure 5 (Beardsley, 1992, p. 100). These tests seemed to reveal a dismal state in science education within the United States.

There are, however, differing interpretations of results of international tests and the standing of the United States in these tests. The work of Husen (1983), chairman of the International Association for the Evaluation of Educational Achievements (IEA), addressed international testing and the comparison of results as "Comparing the Incomparable."

He suggested that the different systems of secondary education, U.S., European, Japanese, and other industrial nations are in many ways incomparable. The United States' system is comprehensive and "...accommodates all or most of the students from a given area under the same roof" and differentiates only by means of programs and ability grouping or homogeneous grouping.

The western European system is a selective system that is characterized by "...the transfer of selected elite from primary to secondary academic school before the end of mandatory schooling" (p. 458). This selection occurs through the use of entrance

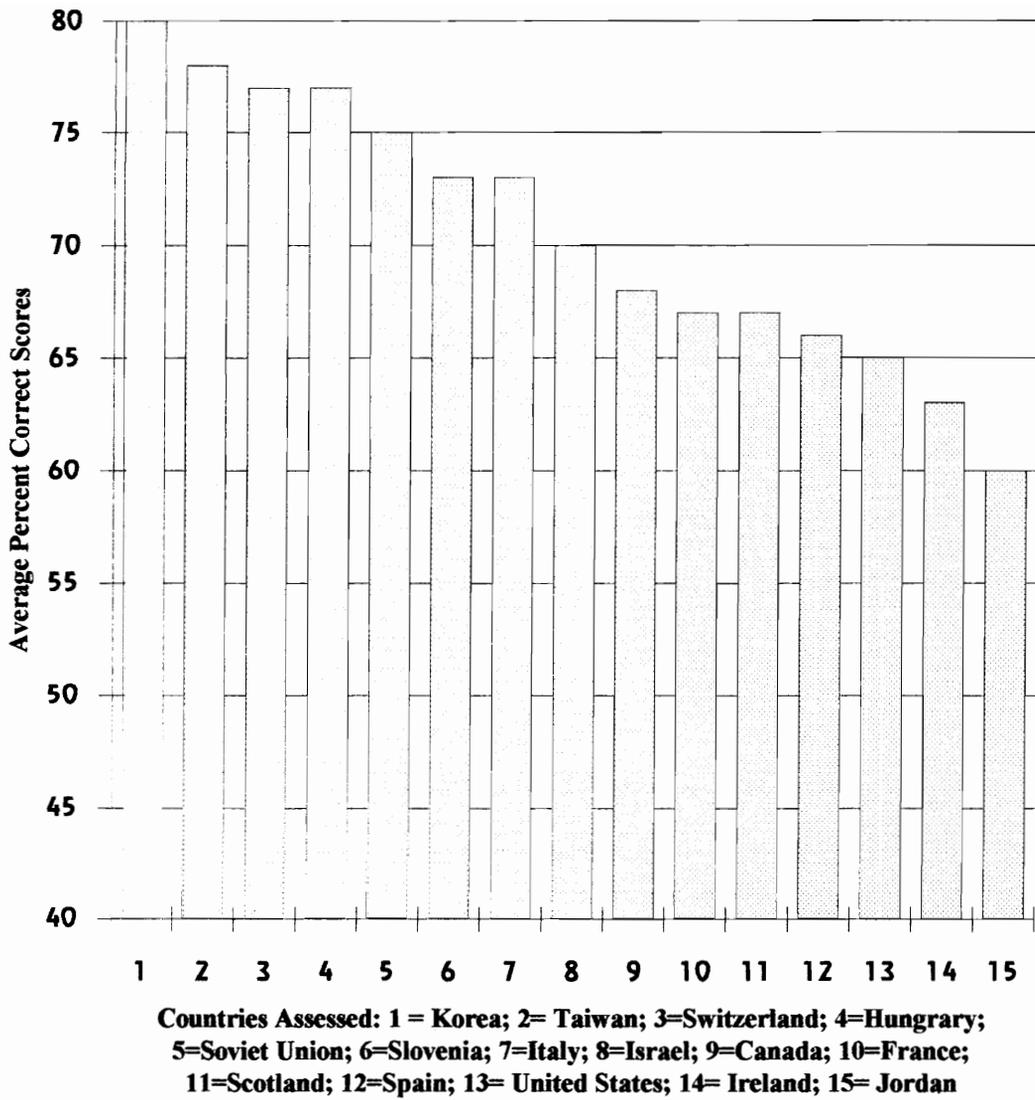


Figure 5: Graph Showing the Rank of the United States in the 1990-1991 Study of International Assessment of Educational Progress in the Area of Scientific Knowledge. Adapted from Beardsley, 1992, p. 100.

examinations. Husen pointed out that U.S. high school seniors account for about 75% to 85% of the relevant age group studied; in Sweden, 50% and in the Federal Republic of Germany 15% (p. 459). He said that it is not fair to compare mean achievements between students in these countries because the proportions of the relevant age group vary with countries. Husen suggested as a more fair method, the comparison of "equal portions" of relevant age groups. In the case of science, when the IEA study compared the top 9% of relevant age groups in industrial countries, they found that "...the countries with a high retention rate experienced sharply increased means. The U.S. doubled its mean and scored higher than Germany and France" (p.460).

Even though Husen's interpretation of international tests gladdens the hearts of some United States' science educators, the published results of these tests in the popular media cause discontent with science education among the populace and governmental agencies. This is not to say that science educators do not or need not worry about the state of science education in the United States, but it does reveal the importance placed on the results of testing.

Science For All Americans cites both national and international tests showing that the United States "...is failing to adequately educate too many students--and hence failing the nation" (AAAS, 1989, p. 11). The prevailing feeling in society is one of a necessity to educate citizens capable of using scientific processes and capable of adapting to new technological conditions. This type of citizen is able to help the United States to resume its role as an economic world leader.

America 2000 supports this kind of rhetoric--"...ensure that every American adult is literate and has the skills necessary to compete in a global economy..." and "There's a special place in inventing the New American School for the corporate community...the cooperate community can take the lead by creating a voluntary private system of World

Class Standards for the workplace (*America 2000*, 1991 p. 4, 7). A scientifically literate workforce is an important product of science education in today's world.

Economic conditions of the nation tie into international test results when highly technical areas of world market competition seem to reflect the scientific training of the *workforce*. International tests show some of our strongest business competitors in world markets surpassing us in fields of scientific knowledge. "Most of the education reports of the 1980s have been motivated by the confluence of two different growing public concerns....America's seeming economic decline....and being ranked near the bottom in international studies of students' knowledge of science and mathematics" (AAAS, 1989, p.153).

Another concern of American science educators is the amount of science instruction students receive. Compared to and analyzed in terms of the amount of science education of students in other countries, the United States usually comes out deficient. Bill Aldridge (1992), executive director for the National Science Teacher's Association and the SS&C reform effort, stated that needed changes in secondary school science "...are, in part, suggested by analysis of science programs in other nations, particularly the USSR and the People's Republic of China" (p. 1).

All students in these countries take several years of biology, chemistry, and physics. The fact that other nations require science and math of their students every year through secondary schools, in a spiraling conceptual curriculum, and the fact that they score better on international tests, helps to support SS&C 's views. If these foreign nations produce better science students, usually defined as ones who can do the best on international tests, then it appears that what we need to do is what they are doing.

The typical student in Japan takes at least two years of science and two years of mathematics. The typical high school student in the United States may have either a

physical science or earth science in the ninth grade and biology as the terminal science course in the tenth grade. The Japanese school day is 225 days long, so over the period of the high school years, this amounts to 25% more schooling than American students. Also, a larger percentage of Japanese students (90%) finish the twelfth grade as compared to Americans (75%) (Rohlen, 1985/86).

"It would not be an exaggeration to say that in many respects the upper half of Japan's graduating high school students possess a level of knowledge and the analytic skills equivalent to the average American graduating from college" (Rohlen, 1985/86, p. 30). Even those who are not in the upper half of the graduating classes of other industrial nations have a more thorough background in science.

In 1991, as President Bush presented the National Educational Strategy, he pointed out that the competitiveness of the United States depends upon the equal education of everyone. "If we want America to remain a leader...we must lead the way in educational innovation....Think about every problem, every challenge we face. The solution to each starts with education" (America 2000, p. 2). Bush presented six educational goals in his address to the nations' governors concerning this national strategy. One of these was to "...make our students first in the world in math and science achievements..." (America 2000, p. 2).

"Once again, Americans [look] to their schools as a panacea; this time, the schools [are] expected to help America keep and improve on its slim competitive edge in the world markets" (Perkinson, 1991, p. 289). Foreign competition, both academically and economically, are part of the driving force behind science reform in the classroom. A perceived means of addressing our academic and economic woes is through the improvement of the scientific literacy of the American populace.

2. Edutech

Education has not escaped technological innovations. The educational community expects teachers and students to be literate in computer use. Classroom instructional methods emphasize the use of computers and computers have become important learning tools in all areas of education, with software available for all grades and subjects. Computers are motivational tools, instructional tools, and administrative tools for schools.

Computers tie into multimedia presentations that provide classrooms with various and numerous examples, pictures, films, and instances of the topic under study. Computers provide some classrooms with worldwide communications through various bulletin board services and other networking facilities. Science classrooms no longer limit students to their classrooms', schools', or communities' views, but through computers students can talk to and dialogue with others around the world.

In the science laboratory the computer is a tool for measuring and data analysis. In some cases, the computer is the science laboratory. Through use of simulations and games, students do their *hands-on* science with computer programs. From grades K-12, computer programs in science provide different and new opportunities for students. The world of the science laboratory is something other than one of test tubes, petri dishes, balances, and thermometers. The quantification and the doing of scientific experiments has a new tool in the computer.

Fisher, a writer for *Popular Science* (1992a, 1992b, 1992c), referred to this new type of technological instruction as *edutech*. In one of a series of articles, "Crisis in Education," Fisher examined technological aspects of science education. The use of technology in classrooms represents a means of improving science education. Computers and other technological accessories are a way to lower the pupil teacher ratio, attract

students to science, and allow students to actually do science. Potential benefits of technological innovations in the science classroom seem to be many.

Fisher presented descriptions of school systems that have entire science classes based on interactive videodiscs. Videodiscs replace textbooks and simulated science replaces *real* science. Students work with "...radioactive materials, handle explosives and pour sodium metal into a lake -- all with great enthusiasm, but no risk" (Fisher, 1992c, p. 94).

The use of high technology in the classroom does not mean that significant changes in instructional procedures occur. The educational researcher, Sarason (1990) noted that teachers usually adapt computers into the established classroom organization. Many times, new technological tools in the classroom lack appropriate "grease" to keep them going. Educational software frequently leaves much to be desired. Students can just as easily accomplish the mere reading of text and answering questions with old technology like books, paper, and pencils.

Appropriate and skillful use of new technology by the classroom teacher is a challenge. Fisher (1992c) described the reality of computers in the classroom; "While most teachers want to use computers, few consider themselves adequately prepared to teach with them. Most applications remain that of isolated drill and practice; in general, classrooms today resemble their ancestors of 50 and 100 years ago" (p.95). Fisher's statement brings out the need for reform in science classrooms. What can be done to change conditions in classrooms and to bring new ideas and instructional methods into them? Several studies of the current state of science education address this question.

3. Studies of Science Education:

In the late 1970s, *Project Synthesis* analyzed data from some National Science Foundation (NSF) studies and the report of the National Assessment of Educational Progress (NAEP). The purpose of *Project Synthesis* was to examine science education as it existed at the time and to make recommendations for future activities (Kahl & Harms, 1981). The project members established five focus groups to examine: (1) biology, (2) physical science, (3) inquiry, (4) elementary school science, and (5) science, technology, society.

Organizing the data into four cluster goals: (1) Personal needs, (2) Societal Issues, (3) Academic Preparation, and (4) Career Education Awareness (Yager, 1981), this group found a "...growing mismatch between the practice of science education and the needs of individual students and our democratic society" (Harms, 1981, p. 113). The actual state of science education showed:

- (1) a low priority given to science education in schools,
- (2) a dominant role given to textbooks,
- (3) the major goal of instruction was for development of basic knowledge for academic preparation, and
- (4) that teachers made most of the important decisions about content, text and instructional methods.

Based on these findings, *Project Synthesis* made recommendations to rethink goals of science education in order to prepare *most* students "...to use science in their everyday lives, to participate intelligently in group decisions regarding critical science-related societal issues and to make informed decisions about potential careers in science and

technology..." (Harms, 1981, p. 119). To reformers, these goals were as important as those of preparing a *few* students to advance in science course work. Ideas presented by *Project Synthesis* are apparent in Project 2061, STS, and SS&C in that they all stress scientific literacy for ALL Americans.

Another study, the 1986 *National Assessment of Educational Progress* (NAEP), as reported in *The Science Report Card*, (Mullis & Jenkins, 1988), showed that reading science textbooks was the most often used instructional activity reported by students. "Over half of the students at all three grade levels (3,7,11) stated that they read textbooks daily or weekly, while most other kinds of learning opportunities are neglected" (p. 99). The *Science Report Card* lists the following trends in today's science classroom:

- (1) Science instruction continues to be dominated by teacher lectures and textbooks,
- (2) Activities such as experimentation and the use of scientific equipment remain comparatively rare and
- (3) The instructional activity reported most often by students was reading science textbooks (Mullis & Jenkins, 1988, p. 99).

Four years later, *The 1990 Science Report Card* (Jones, et al., 1992) also cited these same three trends in science classrooms. "Lecturing and the use of textbooks remain a mainstay in many science classrooms..." and "...students in many high school science classrooms are not gaining experience with laboratory activities" (p. 5).

In most instances, secondary science teaching remains a traditional transmission style of instruction. Memorization of terms and lack of hands-on relevant science still dominate the classroom (Yager & Penick, 1987; AAAS, 1989; Jones, et al, 1990; Fisher,

1992a; NSTA, 1992a, 1992b). *The 1990 Science Report Card* provides data about classroom practices. Tables 9-12, on the following pages, display some of this information.

Table 9 shows data concerning the use of textbooks, discussions, and problem solving that takes place in science classes as reported in eighth and twelfth grade classrooms. These students were asked how frequently they performed certain activities in their science classes. These data support the claims made by educators that reading a science textbook is one of the most frequent activities done in science classroom.

Table 10 displays data about giving reports and doing experiments in science classes. These data reveal that about one-half of the eighth and twelfth grade students seldom practiced communication skills in science classrooms and that the majority of students had little experience with laboratory work on a weekly basis.

Data concerning curriculum decisions made by science teachers and instructional resources available to them are shown in Table 11. This table reveals that teachers have a great deal of control about how they teach, could use more materials, have a fair amount of freedom concerning the curriculum, but that many still rely on the textbook as the main informational source.

Table 12 shows data about teachers' instructional approaches in science classes. Eighth and twelfth grade students asked about the frequency their teachers used different instructional approaches in the classroom reported the lecture method as the one most often used. Methods that call for student skills such as reasoning, writing, and forming opinions, seem to be too often neglected by teachers.

Table 9: Students' Reports on Textbooks, Discussions, and Problem Solving in Science Class*

When you study science, how often do you...?	Several Times a Week of More	About Once a Week or Less	Never
Read a Science Textbook			
Grade 8 Students	60%	30%	10%
Grade 12 Students	46%	29%	25%
Discuss a Science News Event			
Grade 8 Students	34%	47%	20%
Grade 12 Students	25%	48%	27%
Work on a Science Problem			
Grade 8 Students	41%	41%	19%
Grade 12 Students	44%	31%	25%

* This table is adapted from Table 4.6 in *The 1990 Science Report Card* (Jones, et. al., p. 86), NAEP's Assessment of Fourth, Eighth, and Twelfth Graders.

Table 10: Students' Reports on Giving Reports and Doing Experiments in Science Class*

When you study science, how often do you...?	About Once a Week or More	Less Than Once a Week	Never
Give an Oral or Written Science Report			
Grade 8 Students	14%	38%	49%
Grade 12 Students	13%	34%	53%
Do Science Experiments			
Grade 8 Students	41%	38%	21%
Grade 12 Students	51%	24%	26%

* This table is adapted from Table 4.7 in *The 1990 Science Report Card*, (Jones, et. al., p.87) NAEP's Assessment of Fourth, Eighth, and Twelfth Graders

Table 11: Eighth Grade Science Teachers' Reports on Curriculum Decisions and Instructional Resources*

	Strongly Agree/ Agree	No Opinion	Disagree/ Strongly Disagree
I have a great deal of freedom in making decisions about the way I teach my science classes.	91%	2%	7%
My facilities for teaching laboratory science are adequate.	56%	6%	39%
I am well supplied with instructional materials and resources.	56%	9%	35%
I have a great deal of freedom in making decisions about curriculum.	59%	12%	29%
I rely primarily on textbooks to determine what I teach.	48%	7%	46%

* This table is adapted from Table 5.4 in *The 1990 Science Report Card*, (Jones, et.al., p. 95) NAEP's Assessment of Fourth, Eighth, and Twelfth Graders

Table 12: Students' Reports on Teachers' Instructional Approaches in Science Class*

In science class, how often does your teacher...?	Several Times a Week	About Once a Week	Never
Lecture			
Grade 8 Students	61%	27%	13%
Grade 12 Students	76%	13%	11%
Demonstrate a scientific principle			
Grade 8 Students	42%	41%	17%
Grade 12 Students	56%	32%	12%
Ask about reasons for experimental results			
Grade 8 Students	40%	44%	17%
Grade 12 Students	48%	39%	13%
Ask you to write up an experiment			
Grade 8 Students	13%	39%	48%
Grade 12 Students	18%	51%	32%
Ask for an opinion about a science issue			
Grade 8 Students	32%	42%	26%
Grade 12 Students	30%	43%	27%
Ask you to use computers			
Grade 8 Students	6%	15%	79%
Grade 12 Students	7%	25%	68%

* This table is adapted from Table 5.5 in *The 1990 Science Report Card*, (Jones, et. al., p. 97) NAEP's Assessment of Fourth, Eighth, and Twelfth Graders

Other similar reports such as, *Educating Americans for the 21st Century* (1983); *A Nation at Risk* (1988); *Science for All Americans* (1989); *America 2000* (1991), show that there is a genuine need for reform in science education. The picture painted by *Edutech* is more the ideal than the reality of science instruction in today's classrooms.

Today's reform efforts address instructional and curricular problems such as: rote memorization of facts, use of too many technical terms, lack of relevance, scientific illiteracy of the American public, poor scores on international tests by American students, and the exclusion of problem-solving and decision making processes from curricula.

It is not only secondary school science that engages science reformers. The results of international testing support the fact that students of all ages are learning some science, and it is now recognized that elementary children need to be better prepared in science ((Mullis & Jenkins, 1988; Louchs-Horsley, Kapitan, Carlson, Kuerbis, Clark, Nelle, Sachse, Walton, 1990). These authors pointed out that in many elementary schools, science is not considered a basic to the elementary program. "Science is rarely taught at the elementary level, and when it is taught, it's often at the end of a long school day" (Louchs-Horsley, et. al.,1990, p. 4).

The lack of science training, as cited earlier by Project 2061, may be one factor in the elementary teacher's ability and desire to teach science. Louchs-Horsley, et. al.(1990), reported that typical approaches to science in the elementary school "...emphasize discrete topics, uncoordinated facts, and disembodied vocabulary" (p.14). From this, it appears that secondary and elementary schools share common problems in science instruction.

II. Science, Science Education and the Science of Education

1. The New Image of Science:

The image and conception of science and scientists have changed over the last forty years (von Glaserfeld, 1991; Hodson, 1991; Siegel, 1991). The picture of today's scientists is one who "...is driven by prior convictions and commitment guided by group loyalties...petty personal squabbles and whose personal career motivations give the lie to the idea that the scientists yearns only, or even mainly, for the truth" (Siegel, 1991, p.45). However, it is just within the past two decades that this new understanding of science has begun to make its way into the educational arena. With the new image of science there emerges a new image of what science education should be. The philosopher Siegel, suggests that a pluralist science education is necessary. His pluralist view of science "...recognizes that science is never final or certain, but is always subject to amendment and revision on the basis of additional evidence or novel theoretical considerations" (p. 54).

Scientific knowledge today is not science in the Baconian sense of objective reality, but constructed knowledge resulting from social processes. "The criteria of truth and acceptability are determined by the community, and scientific knowledge is recorded for the community in a style approved by the community" (Hodson, 1991, p. 26). Scientific knowledge today is viewed as a human process, a human construction of ideas and theories within a community of practicing scientists. The subjective aspects and theory-laden observations of scientists do not produce the ultimate truth (Yager, 1991b). Hodson (1991), a science educator, says that science is the product of a complex social activity.

Science for students usually comes to them in the form of a textbook, but this textbook knowledge does not represent the whole story behind scientific knowledge. The chemist, Bauer (1992) stressed the point that scientifically literate people must realize the

difference between textbook science and frontier science. Science educator, Duschl (1990) referred to much the same situation in regard to scientific theories and called these *center level theories* as opposed to *textbook science* and *fringe level theories* as opposed to *frontier science*.

Textbook science (central level theories) is science that has met the tests of time and that which comes closest to the perceptions of nature. It provides a core explanation, has no competition, is based on solid observations, and sets standards for inquiry (Duschl, 1990, p. 62). It is the science that results from the consensus of the community of scientists (Duschl, 1990; Hodson, 1991; Bauer, 1992).

Frontier science is the new and the different. It is the new science that has yet to become part of the community of practicing scientists. Fringe theories (frontier science) are crank ideas, new explanations, grand speculations, and have many competitors (Duschl, 1990, p. 62). In schools, textbook science, or what some educators refer to as *final form* science, is what is taught.

Today, textbook science is often called into question as the scientific knowledge base that teachers teach. The realization that scientific knowledge is produced through an interactive social process has effects on the philosophy of science education. Modern science educators concern themselves with teaching scientific concepts and processes, but they also see the nature of scientific knowledge and its activities as important concepts for the classroom.

There is a growing movement for the inclusion of the history and philosophy of science in school science instruction. Educators believe that an understanding of the source of textbook science and the struggles and conflicts involved in this knowledge being accepted by scientists is important to a scientifically literate person. "A sense of

history can give the student a feeling for the movement, progress, and continuous change inherent in science" (Kauffman, 1991, p. 187).

An understanding of frontier science and its role in the scientific process of formulating textbook knowledge is also important. The current reform movements in science education reflect these concerns and ideas. Even new learning theories in science education reflect the idea of science as socially constructed knowledge.

2. Constructivism and Science Education:

The 1980s and 1990s have witnessed the rise of constructivist principles of learning in science education (von Glaserfeld, 1991). Constructivist science educators view learning as a process by which individuals acquire data through their senses and then through a process of assimilation, adjust that data to fit pre-existing concepts or cognitive schemes already present in the mind (Bodner, 1986).*

Constructivist educators recognize that knowledge cannot be transmitted by words alone. They support the idea that learning does not depend upon what teachers "teach," but depends upon the interactive process of students encountering information and how they process it (Yager, 1991b). Constructivist science educators recognize that learning is not a passive process, but must involve the active participation of students in learning (Yager, 1991b; Lave & Wenger, 1991). "Constructivist teachers would tend to explore how students see the problem and why their path towards a solution seemed promising to them" (von Glaserfeld, 1991, p. 129).

As a result of the constructivists' ideas of learning, science classroom teachers who incorporate constructivist principles establish classrooms where students share knowledge,

* Often, as described in the citation from Bodner, constructivist principles deal mainly with the internal cognitive domain of the individual. However, other constructivist educators stress the role of social interaction and language use as described in the following paragraphs.

discuss opinions and ideas, experiment, and develop consensus knowledge of natural phenomena. The science educator and STS advocate, Robert Yager (1991b), described the constructivist learning model as one in which students actively engage in the learning process through group situations. Within groups, students discuss approaches to problems, issues, and situations for which they seek an answer. Today's science education reformers recognize that "[k]nowledge is coconstructed through interactions with others" (Wheatley, 1991, p. 19). The social situations and interactions of students becomes important from a constructivist point of view.

Viewing mathematical and scientific knowledge as a learner activity rather than an independent body of "knowns" leads to quite different educational considerations....attention shifts to establishing learning environments conducive to children constructing their mathematics and science in social settings....such learning environments provide opportunities for children to share their ideas with peers, both in small groups and within the society of the classroom (Wheatley, 1991, p.12).

More recent science education writers broaden the scope of constructivist principles and expand the importance of social interaction *and dialogue* among students. These educators stress the role of language use in learning situations (Lave & Wenger, 1991, Glasson & Lalik, 1992). In support of the constructivist principle that students must be active participants in the learning process, *social constructivists* recognize that "[l]anguage is part of practice, and it is in practice that people learn "(Lave & Wenger, 1991, p.85). It is the interplay between language and action that distinguishes social constructivists from other constructivists.

Educators Glasson & Lalik (1992) suggest that social constructivism is advantageous to science educators in that "...it allows for the development of curricula in which students' reciprocal use of language and action...takes on a much more valued role than the development of internal conceptual frameworks" (p.404). They suggest that learners negotiate meanings of their experiences through language use. Therefore it is important for science teachers to develop an instructional plan that encourages the use of language. Glasson and Lalik (1993) suggest such things as "...open-ended questions, creative writing, students' explanations, and classroom dialog..." to involve the interactive and reciprocal use of language in science learning processes (p. 188).

All three of the major reform movements, STS, Project 2061, and SS&C support constructivist learning principles and call for instructional procedures that enhance social interaction and communication of students. But, even though research literature on science education and the reform movements underway today expound a social constructivist approach, many science classes in the secondary schools present a different picture. Research shows that teachers' understanding of the nature of science "...trails developments in the philosophy of science by 20 to 30 years" and evidence shows that "...many teachers subscribe to an inductivist view of science, a view long since abandoned by philosophers" (Hodson, 1991, p. 20). The inductivist view allows teachers to be transmitters of scientific truth, not *foremen* in a *construction area* of scientific and technological understanding and growth and thus they continue the transmission mode of instruction. Again, the reality of most of today's classroom instruction does not yet incorporate the ideas reformers have suggested since the late 1970's.

III. Aims of Science Education

In 1989, the broad aim of education described in *Science For All Americans*, was; "...preparing people to lead personally fulfilling and responsible lives" (p. 12). In 1987, the educators, Yager and Penick asked the questions;

Is not the major goal for public education the production of an informed electorate and a total citizenry as effectively prepared as possible for the future?" and "Is there any evidence that preparing all people for citizenship--for living productive lives in an age controlled by science and technology, and for dealing with current problems--is not also a way of attracting some of the most talented and the most concerned students as future scientists and engineers (Yager & Penick, 1987, p. 54)?

1. Scientific Habits of Mind and Scientific Literacy:

Science For All Americans, devotes one chapter (12) to "Habits of Mind." Here, the book defines this term as the "...values, attitudes, and skills...that relate directly to a person's outlook on knowledge and learning and ways of thinking and acting" (p. 133). Science educator's today may not train mental faculties as in the late-nineteenth century, but appear to be searching for the same outcomes with a different name--scientific literacy vs. scientific habits of mind.

Project 2061 defines a scientifically literate citizen as:

"...one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and

recognizes both the diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes" (p. 4).

The scientists Hazen and Trefil (1990), wrote that people need to be scientifically literate so that they can understand debates over issues that affect their lives. To them, scientific literacy provides an understanding of everyday events and issues that are as important as "being able to read" (p. xi). They defined scientific literacy as the "...knowledge you need to understand public issues...a mix of facts, vocabulary, concepts, but more general, less precise knowledge used in political discourse" (p. xii).

Hazen and Trefil divorced the *doing* of science from the *using* of science. It is the using of science that they said constitutes scientific literacy. It is important to have enough background to deal with and understand changes around you -- How will these changes affect you and your children? These are concerns that Hazen and Trefil say are important in a discussion of scientific literacy.

They pointed out that *real science* is a human activity and that it can be a little messy around the edges. To be scientifically literate they suggested that one needs to know "...some facts, ...some general concepts...a little about how science works and how it comes to conclusions, and ...a little about scientists as people" (p. xix).

In the science classroom, Bauer's (1992) ideas about the nature of scientific knowledge elucidate the difference between textbook science and frontier science. Scientific literacy involves an understanding of the nature of scientific and technological knowledge and the nature of scientific and technological processes.

Scientific literacy ties into the idea of world economic and academic competitiveness as discussed earlier in this chapter. Bauer provided some insight into this type of justification of science teaching when he wrote, "Literacy, scientific literacy included,

should be encouraged because it is a good thing, not because it is a necessary tool for something else" (p. 16).

The number one goal, which appears to be a consensus among the three major reform movements, is that of producing scientifically literate Americans.* In response to America's poor results in international testing and the world market, scientific literacy appears to be an answer to our academic and economic problems. A competitive workforce, able to survive and live in a technological society, is part of scientific literacy and science education.

2. Moral Character:

In a society that recently experienced a presidential election in which the Republican party emphasized and ran on a ticket of bringing back *family values*, there evidently exists a perceived notion of a need for values in society. Education, again, rises to the occasion.

Today, *values education* is part of the curriculum at all levels of schooling. Conflicts arise as parents think schools usurp their role in teaching values to their children. Also, questions arise about whose values should be taught. Values education runs into many conflicting situations, from those who want them taught, to those who think school is not the place for this type of education.

Martin (1991), a philosopher of science, suggested that science education and moral education are mutually relevant. One of the goals of science education discussed by Martin is that students acquire certain tendencies to behave in certain ways. This requires

* All three major reform movements emphasize that scientific literacy is for ALL Americans, an idea picked up and expanded by the National Research Council to include a global concept of scientific literacy (NRC, 1993). This is not science to train scientists, although they are included, but a science that provides a common core of scientific and technological knowledge to all students regardless of their origin or destination in life. Scientific literacy for all is an attempt to break the elitism of scientific and technological knowledge and occupations. It is an attempt to make science accessible to all.

the use of scientific knowledge and skills (other goals of science education) in decision making situations. In the education of scientists, Martin said moral decisions enter into choices they have to make about research goals. He said young scientists need moral principles, like respect for human life, integrity, sensitivity, honesty, and fairness in interpersonal relationships (p. 107).

Even though Martin recommended that this training take place through science education classes and he primarily addressed the needs of future scientists, he suggested this same education as good for those who do not become scientists. "The average citizen and voter needs to know how to evaluate the moral acceptability of decisions about scientific research in order to evaluate governmental actions...learning to be fair and honest in science gives one a deeper appreciation of the ethical dimensions of science" (p. 107).

Science educators responded in two ways to the issue of values and moral education. First, new conceptions of what science is and how it works, challenges some of the pre-existing traditional values of science and its role in society. Through a presentation of science as a social process and consensus based knowledge, old myths of the objective reality of science and its representation of the *ultimate truth* erode away. The history and philosophy of science reveal moral and ethical dilemmas of textbook science.

The second means of establishing values education in science is more direct. This occurs through classroom instruction and social activity of students. The primary reform movement involved in this type of values education is Science, Technology, and Society(STS). As its name suggests, STS instruction examines the interdependent roles of science, technology, and society.

STS instruction presents students with problems, issues, and situations that are relevant to their concerns. Students work through these problems and issues and try to arrive at solutions for some of the situations presented. "The concept of STS is presented to students so they will develop an understanding of the significance of the issues and be motivated to acquire knowledge and develop values and skills" (Bybee, 1985, p.85). Values education takes place through interactive processes of student discussions and examinations of current and relevant issues in their lives.

STS instruction intends to produce caring and concerned citizens, citizens who are able to live and fully participate in a democracy. Therefore, science education becomes important and can be justified in what it does if students leave school able to function as scientifically literate citizens in a highly technological society.

Project 2061 also addresses the issue of values. Its supporters visualize the role of science education as a means of providing the knowledge base of both the scientific environment and the social behavior necessary to develop solutions to global and local problems. Project 2061, as well as SS&C, use adaptations of the STS model of teaching to allow students to make closer examinations of science, technology, and society interactions.

IV. The Laboratory Method

It is realized that "...there simply is no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge," but that there are features and modes of inquiry in science that give it a distinctive character. Everyone can use these

features, not just scientists, "...in thinking scientifically about many matters of interest in everyday life" (AAAS, 1989, p. 26).

The laboratory method of instruction is an important concept and method of science instruction. Experimentation takes on new meanings in the late-twentieth century view of science education. Laboratory exercises, scientific inquiry, or student activities today encompass quite an array of possibilities.

1. The Traditional Role of the Laboratory:

Traditional laboratory activities that reinforce concepts, illustrate principles or laws, or demonstrate different concepts are usually the norm in secondary schools.* Late-nineteenth century school laboratories did much the same in that they provided illustrations and demonstrations of scientific laws (Martin, 1885; Morrison, 1888; Morrill, 1888; Zartman, 1888; Harris, 1895; Cornish, 1897; Richardson, 1899).

In the late-nineteenth century when science yielded *truth*, this type of laboratory exercise was justifiable. Experiments, conducted by pupils or teachers, verified the truth of scientific facts and laws that students learned in recitation. To see was to believe! Science education reformers cite verification laboratory exercises as a problem with today's science instructional procedures (Yager & Penick, 1987). Today, different conceptions of science justify different conceptions of the role of the school laboratory.

Laboratory experiments have traditionally been done in situations separate from classroom environments. *Recipes* provided by teachers direct student activity in a sequenced manner so that they obtain the *correct* results. It is a process separated from

* Mullis and Jenkins 1988, and Jones, et.al. 1992, report that in many cases this is not even the norm because little experimentation or hands-on work is done.

instructional procedures of non-laboratory classroom activities and tends to separate activities of the lab from concepts of the classroom.

2. New Views of the Role of the Laboratory:

Reform processes today encompass different ideas of what makes up laboratory exercises. In fact, the indexes to both *Science For All Americans* and NSTA's two books on SS&C, *The Content Core* and *Relevant Research*, do not include the word *laboratory*. The word used today to include what was once referred to as laboratory exercises is *hands-on*.

The term *hands-on* implies more than the term *laboratory experiments* did. Hands-on means having in the hands of the student the *things* under study and includes the use of scientific instruments. It is a means of learning by experiencing (Rutherford, 1993, p. 5). Hands-on involves students in relevant issues and things -- a means of exploring nature and phenomena without following a textbook recipe. While laboratory experiments may include many of these same things, most often textbook instruction requires students to experiment with what the author sees as important and involves using procedures specifically outlined by the author.

The use of modern technology is available to change the concept of the science laboratory. Computer assisted experiments, computers to collect and analyze data, and the ultimate computer simulations characterize changing concepts of the science laboratory. From dissections, physics experiments, plate tectonics, to an entire middle school science curriculum, computer technology expands the possibilities of laboratory investigations.

All three of the current reform movements recognize the importance of student activity in learning processes and in this recognition lies the transformation of the

laboratory into a new type of instructional situation. Instead of textbook, cookbook types of experimentation, pupils become actively involved in issues and problems and *things* relevant to them.

The laboratory method emerges in the current reforms as a more encompassing instructional process. Laboratory experiences become part of the total classroom environment and not some isolated segment of scientific practice that seems to apply only in laboratory settings.

V. Late-Twentieth Century Professional Educators

There are three main types of professionals involved in twentieth century science education. There are the professional scientists, the professional science educator and the classroom teacher. Each of these plays a distinct and important role in science education reform.

1. The Professional Scientists:

Professional scientists are an established group in today's society. The role they play in science education reform is usually that of consultants to advisory boards and committees in their area of expertise. They also provide, through research, the scientific knowledge base taught. The consensus knowledge of professional scientists, in the long run, produces what Bauer(1992) referred to as textbook science.*

* According to Bauer (1992) most, about 90%, of what scientists produce is frontier science, the new and different that is yet to become part of the consensus knowledge base of science (p.48).

They help establish *what* science is taught in schools and they also help establish *how* science is taught in schools. The mystique of the *scientific method*, the influence of laboratory research in science, and the teaching of future science educators determines much of what is found in schools today. The use of laboratory notebooks, science fairs, and the hypothetico-deductive method in classroom experiments comes from professional scientists. Yager and Penick (1987) suggested that the "...science being taught in our public schools models directly the science teaching those teachers were subjected to in college" (p. 53).

2. The Professional Science Teacher-Educator:

The second type of professional involved in science education reform is the professional science educator. Usually educated in some specific area of science and having been actively involved in classroom teaching at some period of their lives, these professional science teacher-educators now prepare future science teachers. Professional science teacher-educators research the *teaching* of science and have the pedagogical expertise that is lacking in most professional scientists.

Although they influence future teachers, it is a limited influence. The amount of time that the professional science educator has with future teachers is extremely small in comparison with the time spent by students with professional scientists in their major fields. Teacher-educators recognize that teachers need a strong background in their subject area and this leads to the long-term association with scientists in the future teachers' field of expertise. The professional scientist, therefore, has much more influence on teaching methods used by future classroom teachers than does the professional science teacher- educator.

3. The Classroom Teacher: ✓

The third type of professional is the classroom teacher. This is the one professional that all others recognize as the key in educational reform processes. It is within the classroom that educational progress is made or not. The classroom teacher holds the key to unlock the world of science and technology to students and is the all-important element in the understanding of scientific knowledge. This is the individual that must have the ability, power, and knowledge to incorporate ideas and concepts of science in a form that students find interesting and relevant. Teachers of science are the ones upon whom falls the responsibility to produce the scientifically literate citizens wanted by our society.

The educational researcher Shulman (1987) identified seven different categories of knowledge base that teachers possess. He described these as:

- (1) content knowledge
- (2) general pedagogical knowledge (broad principles and strategies of classroom management and organization that appear to transcend the subject matter)
- (3) curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers
- (4) pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding
- (5) knowledge of learners and their characteristics
- (6) knowledge of educational contexts, ranging from the workings of the groups or classroom, the governance and financing of school districts, to the character of communities and cultures

(7) knowledge of educational ends, purposes, and values, and their philosophical and historical grounds (Shulman, 1987, p. 8).

Of these seven, Shulman said that it is pedagogical content knowledge that is of most importance to teachers. Pedagogical content knowledge is "...the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). It is this special knowledge base with which both scientists and professional educators need to be concerned in their efforts at teacher education.

In work done by Tobin and Fraser (1987, 1990) on exemplary teachers, they found that successful teachers exhibited strengths in pedagogical content knowledge. These teachers effectively used questions as a probe for student understanding, they provided clear and appropriate explanations and used concrete examples in these explanations, and they anticipated trouble areas and provided highlights of the main points at the conclusion of the lesson. Tobin and Fraser (1987) concluded that "...without an essential content base, teachers are unable to focus student thinking, unable to provide appropriate feedback to students and unable to discuss effectively the content dealt with in different classroom environments" (p. 213).

In researcher Happ's (1987) study on exemplary teachers who were teaching outside of their field, he found that they "...might not always bring about sound scientific understanding in students " (p.78) In fact, these teachers actually made errors of fact in their teaching and missed opportunities to diagnose student misunderstandings.

Shulman identified four major sources for the seven knowledge bases of teaching listed above. First there is scholarship in the content disciplines. This is the major

responsibility of professional scientists with whom students study under in the major area of concentration. The second source of the seven knowledge bases of teaching, is materials of the educational setting, such as curricula, books, etc. The third source is social and cultural phenomena that are related to what a teacher can do. In both of these the responsibility falls more heavily on the science teacher-educator. By providing direct involvement with the teaching process and familiarity with the school organization, and knowledge about human learning and teaching, the professional educator becomes the main source of information for the future teacher.

Both the professional scientist and the professional educator are important in the education of the science teacher. One helps supply the specific content knowledge and the other helps supply the pedagogical knowledge. But, if learning occurs through active participation, then it is perhaps the "wisdom of practice," the fourth source of teacher base knowledge identified by Shulman, that plays the major role in educating teachers and thus in turn, affects the type of science instruction occurring in late-twentieth century classrooms.

VI. Summary

Much the same as in the late-nineteenth century, late-twentieth century science education reformers have their own visions, hopes, and dreams for science instruction in secondary schools. Reformers want a type of science instruction that will produce citizens ready to deal with and face global problems of the scientific and technological age. Science educators want science to be available to *all* students and desire that students emerge from science classes with skills and processes that enable them to live in today's society.

✓ Reformers of science education today hope for science instruction that is relevant to students' needs, instruction that limits memorization of technical terms, expands the boundaries of various science disciplines, progresses from the concrete to the abstract and from the known to the unknown, involves students in numerous and different types of instructional activities, and results in citizens with scientific habits of mind. These are the ideals for which late-twentieth century science educators hope.

Constructivist ideas influence the learning theories associated with science education and the conceptions of scientific knowledge in late-twentieth century. Many of the reform ideals desired today result from the views of science education reformers that scientific knowledge on the part of students, must be constructed by social experiences in classrooms. Constructivists' principles call for active student involvement in many different types of situations. Through the active participation of students within the classroom, new concepts about the kinds of instructional methods used in science classes reaches into many different areas of science instruction. Secondary schools are becoming, in the late-twentieth century, more student-centered in their instructional methods.

Reform ideals and goals have yet to make it to most science classrooms. Statistics and testing show that the reality of late-twentieth century science classrooms is too often the learning of terms and definitions and the absence of experience with real nature. The hopes that science reformers have for the use of new instructional technologies and constructivists ideas are often limited by access (usually associated with lack of funding) and know-how on the part of classroom teachers. The reform movements of the late-twentieth century, however, are providing science teachers, school systems, curriculum developers and other reformers with ideas and visions for something better in school science instruction.

CHAPTER 4

A DISCUSSION OF THE DIFFERENCES AND SIMILARITIES OF REFORM MOVEMENTS IN SCIENCE EDUCATION OF THE LATE-NINETEENTH AND LATE-TWENTIETH CENTURIES

Chapter one posed the question; *Are there common factors that influence reform processes and directions in science education during the two time periods under study?* The answer to this is yes. The historical perspective on science education presented in the previous two chapters, brings out some common factors that influenced science education reform initiatives in the late-nineteenth century and late-twentieth century:

- (1) the aura of the scientific and technological times;
- (2) the role of the United States in the world;
- (3) influences of foreign countries;
- (4) prevailing learning theories;
- (5) the ever-present desire for laboratory instructional methods;
- (6) conceptions of the nature of science and technology and their role in society;
- (7) the need for an intelligent citizenry capable of dealing with the new technologies of the age (scientific literacy);
- (8) the development of moral consciousness and social concern in students;
- (9) dissatisfaction with the current science education agenda; and
- (10) organized reform efforts by educational or other agencies, individuals, or professional educators at all levels.

As a result of the sharing of these common factors between the late-nineteenth century and the late-twentieth century, some obvious similarities exist in the terms and rhetoric used to describe science education reforms in both eras. Because of these similarities, the question posed in chapter one recurs, *Are reforms of the two decades before the turn of the two centuries really as similar as they seem?*

In the search for an answer to this question, the author presents highlights of the work and ideas of some individual late-nineteenth century science educators, in addition to the ideas of the one major reforming group, the Committee of Ten. Tables and discussions provided in this chapter make known the reform ideas of the Committee of Ten and the ideas of some other science educators who were not members of this committee, but published in journals and magazines as independent agents. These educators suggested new ideas about science instruction and in the author's view they were reformers of science education.

Most late-twentieth century science education reformers make known their ideas through the eyes of the three major reform efforts of STS, SS&C, and Project 2061. The fact that today's reformers associate with major organizational initiatives have made an extensive review of modern day periodical literature by *individual* authors less critical for the characterization of this period than that needed for study of the late-nineteenth century. The majority of today's reformers are part of, or advocates for, one of the three major reform movements now underway. STS, SS&C and Project 2061 epitomize the concerns and recommendations of science education reformers today.

Discussions of the influential factors shared by the two different eras occur in the context of the five organizational headings used for purposes of comparison throughout chapters two and three. An examination of the differences and similarities in the factors involved in influencing the perceived problems, the goals and aims, the philosophy of the

nature of science, the psychology of learning, the use of the laboratory method, and suggested reforms in science education, appear in the chapter sections that follow.

I. Common Factors Associated With, Shared by, and Influential on Problems and Concerns of Science Education Reform in the Late-Nineteenth and Late-Twentieth Centuries

When dissatisfaction with the current science educational agenda arises, whatever the century, the need for reforms become apparent. Dissatisfaction results from different sources. There may be dissatisfaction with regard to science education outcomes (goals), or with instructional methods and materials. In the following paragraphs the author addresses the problems associated with science instructional procedures in both centuries, while dealing with the problems related to the goals of science education in the second section of this chapter.

Problems shared by the two eras and associated with dissatisfactions about science instructional processes appear through an examination of the periodical literature. Table 13 is a list of some representative science educators, selected from the review of late-nineteenth century literature, and presents what they described as problems with science education. Table 14 is a similar list of representative individuals, programs, and studies of late-twentieth century science education reform efforts and problems identified by them.

The author provides in Table 15 a list of the problems cited most often in the periodical literature of the two different times arranged in order of the frequency of occurrence of those problems in the literature. This table shows that the major problems

Table 13: Late-Nineteenth Century Science Education Problems

Name	Problems	Name	Problems
1887 Mowry	Textbooks begin with long list of terms and definitions to be learned; Some material too deep; Students not prepared.	1889 Allen	No science in lower grades
1887 Cutting	Teaching to test (Regent's exam); Lack of competent teachers – teach what they are assigned; Too conservative teachers – still like recitation method; Poor college training in science for teachers.	1890 Jordan	Book dependent; No contact with nature; No information worth having; Class of scattered information; Time divided among too many sciences – "smatterings"; Study books instead of nature; Poor books; Mainly memorizing definitions – not relevant to the child; Teachers don't know how to teach "If the book comes to them wrong-side up, their teaching is forever inverted."; Teaching of science is not real – "only dust-heaps of old definitions."
1887 Lewis	Poor apparatus; Principals not educated in science – don't encourage it at their schools.	1892 Macmillan	Neglect world of living (plants) for "word-worries"; Memorization from the textbook.
1887 Rappleye	Teachers know only what's in textbooks.	1895 Jackman	Specialization and isolation of subjects in high school; Poorly trained teachers.
1888 Dryer	Costliness of equipment; Scarcity of good books and teachers; Undeveloped state of pedagogy of science instruction; Things that science teaches - insight, constructive imagination, induction, generalization, are not easily estimated in percentages.	1895 Harris	Presented as uninteresting and without educational value; Lack of apparatus; Lack of public support.
1888 Ballard	Preliminary courses – definition cramming; Authoritarian teachers – must see what they see; Danger of students seeing science only in apparatus and not in the everyday world; No logical sequence of courses; College influences courses of study.	1896 Paddock	Classroom science is of no use in the practical world; Too much mental exercise.
1888 Morrill	Imperfect knowledge about the laws of mental growth; Textbook dependence; Lack of time; Lack of funds; Lack of trained teachers; Students doing work mechanically – not thinking or observing; Little science required for admission to college.	1897 Ward	Lack of knowledge on part of the teacher about subject and how to teach it; Teachers overworked; Neglect of study of living things in their environment; Textbook – dependence upon authority.

Table 14: Late-Twentieth Century Science Education Problems

Name	Problems	Name	Problems
1987 Yager and Penick	Mismatch between what's in the schools and what's needed; textbook used most of time; little if any direct experience; instruction centers on word mastery; labs mostly verification; 90% high school graduates scientifically illiterate; most instruction done through lectures and question-answer format; teachers unaware of research about learning and instruction.	1992 Fisher	Little science in elementary schools; too much taught by transmission mode; decline in student experimentation; 2400-3000 new terms in a typical text; rote memorization for tests; poorly trained teachers; ineffectual over-ambitious textbooks; over-loaded curriculum; outdated and inadequate curriculum.
1989 Project 2061	Most Americans are scientifically illiterate; US students near bottom in international tests; poor preparation of teachers; textbooks support rote learning of facts; few elementary teachers with rudimentary science background; Jr. and Sr. high school teachers do not meet reasonable standards of preparation; teacher education institutions tolerate deficiencies; teacher have heavy work loads; science textbooks and methods of instruction impede progress.	1992 Beardsley	Classes too large; too little preparation time for teachers; inadequate teacher training; shortage of funds for supplies; uninspiring textbooks; error-filled texts; standardized tests trivialize knowledge -- teach for facts.
1990 Science Report Card	Schools do not place a special priority on science; little experimentation by students; lecturing and use of textbooks remain a mainstay in classrooms; teachers rely on textbook to determine what they teach.	1992 Scope, Sequence and Coordination	Mastery of facts discourages real learning; tradition; standardized tests support fact mastery; 3/4 students take no science after the tenth grade; layer-cake curriculum; no relationship between sciences; unconnected information; sequencing and tracking excludes some students; elementary students study science by reading about it; variation from school to school; high school courses viewed as college prep.; not enough time spent on each science; textbook driven.; not relevant.
1991 America 2000	Our world competitors are in the process of reforming education; American students near bottom of international comparisons; tradition.	STS 1980-today	Lack of framework which emphasizes application and problem solving; testing, memorization of facts, not relevant to students.

Table 15: Most Commonly Cited Problems of Late-Nineteenth and Late-Twentieth Centuries Science Education

19th Century	20th Century
1. Poorly trained teachers.	1. Rote learning of textbook terms and definitions.
2. Textbook dependence and memorization of terms and definitions.	2. Textbook dependence.
3. Recitation main instructional method; Lack of equipment and funds; Underdeveloped state of pedagogy; and no contact with nature.	3. Teaching to tests -- standardized tests support fact mastery; Poor preparation of teachers; No direct experience with phenomena; and lecturing the main instructional method.

identified by the late-nineteenth century educators were much the same as those identified in the late-twentieth century -- rote memorization, textbook dependence, poorly prepared teachers, teaching too much in too little time, lack of equipment and little or no contact with nature.*

1. Memorization and Textbook Dependence:

From Tables 13, 14, & 15, it is obvious that one major dissatisfaction with science instruction shared by both eras is memorization of materials from textbooks. Memorization, as an instructional method, occurred too often in the late-nineteenth century classroom and remains too much a part of science instruction in the late-twentieth century school room.

Late-nineteenth century students memorized terms, definitions, and whole pages of material to recite to teachers for grades. Today, memorization is nowhere near the exact *word for word* recitation required for the mental discipline needed by students in 1893. Students no longer stand, "toe the line," and recite pages of memorized materials to the teacher.

Today, memorization usually involves learning and defining new and most often highly technical terms and concepts, such as the Krebs's cycle, photosynthesis, or elements on the periodic table. These are problems enough in themselves, but this gives an example that shows that the process of memorization is different (students may sometimes actually use their own words and not the textbooks'), and perhaps a less de-humanizing experience than in the late-nineteenth century.

* This last aspect of common problems shared by the two reform periods under study, contact with nature, is discussed in a separate section on the role of the laboratory method that occurs later in this chapter. Some minor discussion of laboratory experiences is included in the topic on poorly trained teachers within this section.

With memorization as a primary mode of instruction, in either the late-nineteenth century or the late-twentieth century, it means that teaching is textbook dependent and that students experience little of nature and natural phenomena. Science educators in both time frames have expressed concerns about science as vocabulary and science remote from nature and life situations. *Science For All Americans* (1989), describes the present state of science instruction as emphasizing "...memory at the expense of critical thinking, bits and pieces of information instead of understandings in context, recitation over argument, reading in lieu of doing" (p.17).

Remember D.S. Jordan's (1890) comments about high school science (quoted in chapter one), -- "It is not real; it is not the study of nature, only dust-heaps of old definitions" (p. 726). Science teaching in the late-twentieth century experiences textbook dependence (see Table 11) and the too often, although more limited, use of memorization as did that of the late-nineteenth century.

The traditional methods of instruction used by late-nineteenth century educators in classical studies was memorization and recitation. With the introduction of science in high schools, late-nineteenth century science educators began to call for a break with tradition and for a different kind of instruction suggested by the very nature of science itself -- the laboratory method of instruction (Lewis, 1887; Dryer, 1888; Ballard, 1888; Jordan, 1890; Nelson, 1893; Weed, 1896). Science educators insisted that the new laboratory approach to science instruction put students in direct contact with nature and natural phenomena, not contact through words and definitions memorized from textbooks.

Although dissatisfaction with the overuse of the instructional practice of memorization is a problem common to and influential on ideas of science education reformers in both eras, there are differences in this factor between the eras. Primarily the difference is in the degree of use of this instructional method and in ideas about traditional

kinds of educational practices best used in science classrooms. Ideas about science instructional methods changed in the late-nineteenth century, from mental discipline, memorization and recitation to the ideas of student laboratory experiences. Today's constructivist ideals of science and science instruction call for even greater changes in instructional methods and the limitation of memorization as the primary learning tool is one of these desired changes.

2. Poorly Trained Science Teachers: v

The 1880s and 1890s cited poorly trained science teachers as a major problem (Cutting, 1887; Rappleye, 1887; Dryer, 1888; Jordan 1890; Jackman, 1895) and it remains a problem one hundred years later (Yager & Penick, 1987; AAAS, 1989; Fisher, 1992; Beardsley, 1992). Towards the end of the nineteenth century and the beginning of the twentieth century, educators perceived that normal schools did not fulfill their expectations (Schurman, 1896; Aspenwall, 1902; Abernethy, 1903). There was a call for the education of teachers at the college and university level.

Having achieved the goal of college educated teachers today, the poor quality of science teachers still ranks as one of the top problems cited by science education reformers (Tables 14 & 15). Project 2061 describes the state of science teacher education at the elementary level as less than *rudimentary* and science and mathematics teachers at the junior and senior high schools as not meeting "reasonable standards of preparation...." This report faults institutions of teacher preparation, licensing bodies, schools and the profession itself with the poor quality of science teachers (AAAS, 1989, p.4).

Compared to the picture of teacher preparation presented by late-nineteenth century educators,* the preparation of late-twentieth century science teachers comes close to the ideal expectations of these late-nineteenth century educators. Science teachers are much better prepared today in both subject matter and in pedagogical aspects of teaching. The ideals of today's reformers call for even better prepared and qualified science teachers in response to the ever increasing expansion and complexity of scientific and technological knowledge bases.

The lack of use of the laboratory method of instruction as cited by educators of both eras, is most likely related to the education of science teachers. Late-nineteenth century teachers received little instruction in science, had little equipment with which to work, and lacked the know-how to incorporate laboratory methods into classroom instruction.

Today, many states mandate the amount of classroom time devoted to laboratory experiences. Laboratory exercises are readily available; most textbooks come with laboratory exercises included as part of the textbook or as accessory laboratory manuals. Guides for preparing and conducting laboratory experiences provide teachers with the necessary mechanical information needed to include laboratory experiences as part of classroom activities. Laboratory exercises, although cited by modern researchers as lacking or perhaps lagging in today's classrooms (Table 10), are not the missing piece of **most** science instruction as they were in the late-nineteenth century.

Today's science teacher training programs address many of the concerns with teacher quality expressed in the late-nineteenth century. Changes in classroom science instruction are obvious from the late-nineteenth century to the late-twentieth century, but

* See Chapter 2, Section V, topic #1, for a description of teacher preparation in the late-nineteenth century.

again, as outside factors influence the ideals of science instructional methods, more change becomes necessary.

3. Textbook Quality:

The quality of textbooks becomes an instructional problem when books determine the curriculum. Textbooks seemed to define the curriculum in the late-nineteenth century as they do in the late-twentieth century, more so than any other factor (Tables 11 & 13). Literature of the late-nineteenth century often cited the poor quality of textbooks (Mowry, 1887; Dryer, 1888). Because of this and the fact that teachers depended upon textbooks so much (Rappleye, 1887; Morrill, 1888; Jordan, 1890; Ward, 1897), some educators did not recommend their use in the classroom (Ballard, 1888; Nelson, 1893).

Scientific American (Beardsley, 1992) describes the current state of textbooks in reporting about *The Textbook Letters*, a bimonthly bulletin of the California Textbook League. *Scientific American* gives examples from the bulletin of gross scientific content errors as well as completely fictionalized stories found in modern day textbooks (p. 101). Project 2061 states that textbooks actually impede progress toward scientific literacy since they inhibit creative and problem-solving abilities in students (AAAS, 1989, p. 14).

Although problems exist with textbooks today, there are differences in this shared concern of the two different time periods. Textbooks today are much improved over those of the late-nineteenth century. Color pictures, tables, and charts, as well as concerns for appropriate reading levels and teacher guidance sections, provide higher quality and more appealing texts than those found in late-nineteenth century science classrooms.

Educators from the two different time periods express the same problems and concerns, but again, even though the words used to express these problems are the same, differences exists in the underlying situations behind these problems.

4. Overstuffed and Undernourished Curricula:

Late-nineteenth century science educators expressed concerns about the number of science courses taught in high schools and the small amount of time spent on them. Jordan (1890) referred to science courses in high schools as *smatterings*, and described them as fourteen weeks in science that gave "...no contact with nature, no training of any sort, no information worth having; only a distaste for that class of scattering information which is supposed to be science" (p. 722).

The number of science courses taught today may be fewer and the time spent in them longer than the many *smatterings* of courses that concerned Jordan. However, even with the number of courses decreased, problems of content inflation exist today. "The present curricula in science and mathematics are overstuffed and undernourished" (AAAS, 1989, p.14). Courses are jammed full of new terms and definitions, as many as 2400 - 3000 in a year (Fisher, 1992b).

As in the late-nineteenth century, today's science teachers have to teach too much in too little time. All the major reform movements today realize this and call for a *Less is More* approach to science instruction. The identification of major topics, themes, concepts, or issues as a curriculum base is a way to eliminate the teaching of terms and the softening of boundaries between the various sciences (AAAS, 1993). One way to accomplish the *Less is More* approach is through interdisciplinary courses.

Several late-nineteenth century educators realized that the separate and logical classification of sciences into biology, chemistry and physics produced isolated knowledge with no realization of the relationships that existed between the various sciences (Martin, 1888; Yonce, 1888; Boyer, 1897; Richardson, 1899). Martin (1888) realized the need to do away with distinct courses. The separation of science courses "...lead[s] students to see no relationship between them" and it was suggested that it was better to study one

thing in light of all the sciences (p. 442). Dryer (1888) suggested that there was no need to emphasize the distinction between chemistry and physics. He suggested that "...those portions of both sciences which are most suitable..." should be studied together (p. 200). Boyer noted "...hard and fast lines which formally separated them [sciences] into distinct sciences [were] becoming obliterated." He suggested that elementary teachers "...are too much afraid of crossing the arbitrary boundaries of their immediate study and thereby frequently lose an opportunity of teaching a truth..." that could otherwise be brought out (p. 958).

These ideas of interdisciplinary science instruction existed when the Committee of Ten developed its high school curriculum around separate science disciplines. Of the science conferences of the Committee of Ten, only the Geography Conference envisioned and recommended an interdisciplinary approach to teaching at the secondary level. The summary report of the Committee of Ten described geography instruction as a study that embraced a "...description of the surface of the earth, but also the elements of botany, zoology, astronomy, and meteorology, as well as many considerations pertaining to commerce, government, and ethnology" (NEA, 1893, p. 32).

The call for interdisciplinary approaches to science teaching resurfaces today. Figure 6 presents Project 2061's conception of the results of today's isolated courses. The idea and suggested need for interdisciplinary approaches to science instruction are not new concepts brought to the reform movements of today. Science educators, one



"I'm on the verge of a major breakthrough but I'm also at that point where Chemistry leaves off and Physics begins, so I'll have to drop the whole thing."

Figure 6: Cartoon Illustrating Interdisciplinary Science

(AAAS, 2061 Today, 2(2):4).

hundred years ago, expressed interdisciplinary ideas about science instruction, ideas that show little difference from today's reform movements.

Reform efforts, of both centuries, address dissatisfactions with science education. In the perceptions of late-nineteenth and late-twentieth centuries' science educators, the preparation of scientifically literate citizens results in the empowerment of individuals to sustain and improve democratic ideals in the United States (Alling, 1881; Dryer, 1888; Yonce, 1888; Jordan, 1894; AAAS, 1989; Waks, 1989). In order to attain these ideals, high quality teachers, textbooks, and instructional methods in science classes are a necessary ingredient. When any of these ingredients does not agree with the concepts of the science education community or meet with public approval, then some educators perceive that the United States endangers its democratic principles.

The comparisons made in earlier sections reveal similar problems that appear to suggest little change in instructional processes from a hundred years ago, but as noted in this section, this is not entirely the case. Only the surface aspects of the problems identified in these two reform periods reveal striking similarities. The theories and ideas behind these problems and the degrees of occurrence of these problems illustrate a different situation. The underlying differences with the dissatisfaction of the science educational agenda of the different eras cause the problems of both eras to be some different, but the common factors that influence these problems cause them to appear to be much the same.

II. Common Factors Associated With, Shared by, and Influential on the Goals and Aims of Science Education Reform in the Late-Nineteenth and Late-Twentieth Centuries

The aura of the scientific and technological times, the need for an intelligent citizenry capable of dealing with technologies of the age, and the development of moral consciousness and social concern in students are some of the factors common to both the late-nineteenth century and the late-twentieth century that influence the goals and aims of science education.

1. Scientific Habits of Mind and Scientific Literacy:

In both the late-nineteenth and late-twentieth centuries, when educators realized that public school science instruction had not attained the goal of preparing a citizenry capable of dealing with problems presented by the scientific and technological times, cries of alarm about the state of public education occurred.

In the late-nineteenth century, Charles Eliot addressed problems with public education in the *Forum* (1892). In the article titled, "Wherein Popular Education Has Failed," Eliot stated, there "...is serious and general disappointment at the results of popular education up to this date" (Eliot, 1898, p.203). He cited as examples of the failure of popular education, the fact that the general public continued to fall under the lure of astrologers, healers, and fortune tellers, and that riots, assassinations, wars, and poor relationships between employers and employees existed.

These social ills provided Eliot with evidence of the failure of public education, and he envisioned a way out of these problems to be the teaching of "...observing accurately; recording correctly; comparing, grouping, and inferring justly; and expressing cogently the results of these mental operations" (Eliot, 1898, p. 220). He described these four

processes as essential in all teaching, no matter what the subject. If good teaching involved these four things, Eliot wrote, then it would result in a population that was able to reason and make sound judgments.

Crowe (1900), an author in *Popular Science Monthly*, expressed similar concerns about the failure of the educational system to "elevate national character." He cited wars, riots, and "disease of the national conscience" as failures of public education to teach people to engage in critical thinking before acting. "If we have expended so much for education and at the same time have lowered our ideal of national greatness, something must be wrong with that education" (p. 91).

To meet these failures of "national weakness," Crowe wrote, "...the scientific studies seem especially fitted" (p.96). With a love for truth and the attitude of mind that would allow one to make correct judgments (the results of scientific studies), Crowe noted the implantation of the first elements of good citizenship in the students' nature (p. 98).

This concern of Eliot's and Crowe's for a population that could use processes of science in order to make intelligent and informed decisions seems very anticipatory of what reformers today suggest when they ask, "Is the proposed content likely to help citizens participate intelligently in making social and political decisions on matters involving science and technology" (AAAS, 1989, p.21)? Scientific literacy, the "...uses of scientific knowledge and scientific ways of thinking for individual and social purposes" (AAAS, 1989, p. 4), was as much a part of the solution to social ills of the late-nineteenth century as it is today.

The concern about social ills in the late-nineteenth century hinged more on an internalist view of the nation. Citizens with scientific habits of mind were to solve American social ills. Today, 1993, the preparation of citizens with scientific habits of mind is for more global concerns. The advancements made in communications increase

our awareness of the wide scope of world problems. Americans recognize that they cannot isolate themselves from these problems because they affect this country and thus they become our problems too.

Science educators now talk of global problems and issues rather than just those facing society at home. *Science For All Americans* suggests that more is at stake in education than just the "individual self-fulfillment" and national interest of the United States. Global issues such as:

...unchecked population growth in many parts of the world, acid rain, the shrinking of the tropical rain forests and other great sources of species diversity, the pollution of the environment, disease, social strife, the extreme inequities in the distribution of the earth's wealth, the huge investment of human intellect and scarce resources in preparing for and conducting war, the ominous shadow of nuclear holocaust... (AAAS, 1989, p. 12).

Science educators from both time periods concerned themselves with developing moral and social consciousness of citizens through scientific habits of mind. Late-nineteenth century educators primarily considered the development of the moral consciousness of the individual citizen of the United States, while today's reform efforts strive for moral and social consciousness education of the citizen of the world.*

The desire for citizens with moral consciousness and social concerns and actions, are common factors that influence the goals and aims of late-nineteenth century science education reformers, as well as those of the late-twentieth century. It was partly the spirit

* Although science education reformers push for a global moral consciousness, there are remnants of nationalistic goals still visible. The desire for America to be first in math and science education in the world is an example of one nationalistic goal today (*America 2000*).

of the scientific and technological times that established science instruction as a means of providing these desired qualities of citizenship. Since a democracy is only as good as the citizens involved in it, it becomes important in scientific and technological times that all citizens have some knowledge of scientific processes and facts. Both the late-nineteenth and the late-twentieth centuries' concepts of science education exhibit traits influenced by the role of science and technology in their respective societies.

2. Science for ALL:

There was an unanimous agreement among the different conferences of the Committee of Ten that all students should be taught science in the same way and to the same extent in any course in which they were enrolled (NEA, 1893, p. 17). The committee did not suggest that all students enroll in the same courses, but in the courses in which they were enrolled, they wanted students taught the same.

The education of students to deal with situations in life, and not specific education for factual knowledge or college admission were goals of late-nineteenth century science educators. Education for the common man, popular education, and practicality were reform cries of the late-nineteenth century (Jordan, 1890; Eliot, 1898). Today a similar cry emerges from reform movements, such as STS, SS&C and Project 2061. Project 2061 states, "Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives"(AAAS, 1989, p. 12).

Today's reforms are calling for a common core of learning. -- the same science for ALL Americans. Project 2061 identifies and recommends learning goals that all students should be able to attain by the time they finish high school. It is pointed out, however, that "...no student should be limited to the common core of learning spelled out in [the] report" (AAAS, 1989, p. 20).

The late-twentieth century envisions science instruction in practical terms (as did the late-nineteenth century), Table 16. It is the practicality of science that makes it relevant and interesting to pupils. Skills learned in science classrooms can be applied outside the classroom. Scientifically literate citizens use their scientific knowledge for individual and social purposes. Acquisition of scientific knowledge through the use of real life situations in science classrooms is a demonstration of the practicality of science. Reformers of the late-twentieth century visualize science education as necessary for individuals to function and live fulfilled lives in the highly scientific and technological society that exists. It is also important for society that scientifically literate citizens become concerned, compassionate and involved in solving local, national, and global problems.

Some of the same forces shaped the goals of late-nineteenth century science education reformers and the goals of late-twentieth century science education reformers. However, it appears that the effect of these forces results in a broader concept for the goals of science education and their role in today's world.

Table 16: Most Commonly Cited Goals and Aims of Late-Twentieth Century Science Education

STS	SS&C	2061
1. Science for meeting personal needs.	1. Scientific literacy for all students.	1. Science Literacy for ALL students in the 21st century. (Science education should help students to develop understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. To participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital.)
2. Science for resolving societal problems.	2. To teach science to all students in a coordinated way from concrete to abstract, with practical application.	2. Systemic reform of ALL aspects of K-12 education.
3. Science for career awareness.	3. To know how to ask questions and when to ask them.	3. Curriculum connections among ALL disciplines.
4. Science as preparation for further study.	4. To think critically and to be able to make important decisions based on reason rather than emotions or superstition.	4. Teachers as Professionals designing creative instructional approaches.
		5. Effective teaching and learning through alternative approaches.

III. Common Factors Associated With, Shared by, and Influential on Understandings of the Nature of Science and the Psychology of Learning in Science Education Reform in Late-Nineteenth and Late Twentieth Centuries

The two influential factors on science education reform that show the greatest differences between the late-nineteenth century and the late-twentieth century are the prevailing learning theories and the conceptions of the natures of science and technology and their role in society, Table 17. In the late-nineteenth century, faculty psychology influenced ideas of instruction in general, and positivistic ideas of the nature of science influenced science instruction specifically. In the late-twentieth century, the ideas of social construction of knowledge influence both the approach to science instruction and ideas about the nature of scientific knowledge.

1. Mental Faculties and Positivistic Science:

The picture of the mind with different areas that require discipline and training, governed educational psychology in the late-nineteenth century. As noted in chapter two, the science of the mind, in the form of psychology, was in its infancy and had just started to involve a quantitative approach to education.

Faculty psychology retained an influential role in educational ideas of the late-nineteenth century, particularly with regard to science instruction. The 1880s' and 1890s' science education reformers concerned themselves with teaching processes of science -- observing, reasoning, classifying, grouping, sorting, communicating clearly, and analyzing inductively. To train the faculties of the mind in these skills and to train students to effectively use them in everyday life became the ultimate goals of late-nineteenth century science education.

Table 17: A Comparison of the Philosophy of Science, Prevalent Learning Theories and the Product of Science Education of the Late-Nineteenth and Late-Twentieth Centuries

	Late 19th Century	Late 20th Century
Philosophy of Science	<p>Positivistic; Science as discovery of the "truth"; Baconian in outlook --stress on powers of observation; Science as objective knowledge -- free from human values.</p>	<p>Science as consensus knowledge of practicing scientists. Community constructed knowledge that at the time best explains natural phenomena. Science as social activity --one that incorporates human values.</p>
Prevalent Learning Theories	<p>Herbart -- apperception -- knowledge must come through the senses and build upon pre-existing knowledge. Emphasis on the laboratory method of instruction -- observing, classifying, reasoning, and inductively reaching generalizations. Faculty psychology prevalent -- training of different faculties of the mind.</p>	<p>Constructivism-- Knowledge in the classroom socially constructed; Group learning situations; Knowledge based on prior experiences -- thus the learner must be actively involved -- supports laboratory instructional methods. Involves the study of the nature of scientific knowledge -- since it is a social process, the history, sociology and philosophy become important in science instruction.</p>
Products of Science Education	<p>Students with scientific habits of mind able to function in the new scientific society. Able to "think" and "reason." Able to meet life head-on. Able to lead personally fulfilling lives and contribute to the betterment of society.</p>	<p>Students with scientific habits of mind able to function in the highly scientific and technological society. Able to "think" and "reason." Able to meet life head-on. Able to lead personally fulfilling lives and contribute to the betterment of a more humane and decent society.</p>

The Baconian, positivistic outlook on science of the late-nineteenth century, with its emphasis on observation and induction, affected learning theories incorporated into science education reform. Scientific practices that stressed the use of observational and inductive processes to arrive at facts, and in turn the truth about nature, became part of school science reform goals.

The conceptions of late-nineteenth century science and the role that science played in the educational process were similar. Scientific study proceeded through observation, reasoning, and induction, and science instruction occurred through laboratory methods of observation, reasoning, and induction. The discipline and training of students' faculties of mind in scientific processes was a major aim of late-nineteenth century science education reformers.

2. Constructivism and Post-Positivistic Science:

Today, the three major reform movements in science education accept the post-positivistic view of science. Scientific knowledge does not represent the ultimate truth, but is socially constructed knowledge. It is knowledge constructed by of a community of scientists. This shared, consensus knowledge makes up the world of science in schools, the textbook knowledge of which Bauer (1992) spoke.

Socially constructed views of scientific knowledge help shape learning theories associated with science education today (Table 17). Constructivist principles of learning depict science education in the same social construction mode as that which produces scientific knowledge. Constructivist learning theories state that students must experience, share and discuss their experiences with others in order for them to construct their own understandings. Under this theory, group work in science classes becomes important.

Emulation of real scientists is not a goal or a philosophy of science education reformers today, but real scientists work in groups. They share knowledge and approach problems from a team perspective, and understanding takes place through dialogue and social relationships that build on previous experiences. Science educators see these same types of experiences as a necessary part of students' science instruction.

Today, constructivist views of science and constructivist approaches to science education broaden the scope of science instruction beyond what late-nineteenth century educators suggested. In order to construct knowledge, more than just the processes of scientific inquiry and analysis become necessary. Relevant hands-on exercises are important instructional methods in providing experiences on which students construct understanding. Past experiences, not only of the student, but of historical times, also play a role in today's reforms. From the constructivist point of view, an understanding of where scientific knowledge comes from, and what its nature is, are important concepts for students in today's classrooms.

3. Science and Technology:

Ideas about the relationships of science and technology differ between the two periods under study, and these ideas influence reform efforts in science education. The late-nineteenth century view of science and technology was that of an assembly line in which technologists transformed the ideas of scientists through processes of "...applied research, invention, development, engineering and marketing...into an innovation" (Wise, 1985 p. 229). Edwin Layton (1971), a historian of science and technology, attributed this assembly line concept of science and technology to the scientific revolution that American technology went through in the nineteenth century. He wrote that technology was primarily a craft tradition before the nineteenth century, but as a result of the scientific

revolution of technology it was "...grafted onto science....and was reconstructed as a mirror-image twin of the scientific community" (p. 562).

For science educators of the late-nineteenth century, technology education was not part of their reform efforts, because to them technology was the application of scientific knowledge. Educators described the times as scientific in nature, not technological. In a description, given earlier by the science educator Cobb (1899), of changes that occurred in the past thirty years (1869-1899), most of the things mentioned by Cobb as having changed were technological inventions and not scientific theories or knowledge, yet Cobb referred to these as science.

In an era when scientific knowledge was the truth, the existence of technology as knowledge was unacceptable. The historian of technology, Staudenmaier (1989) wrote, in opposition to the positivistic idea of science, that a conception of science that frees it from "...human feeling and value commitments, a freedom which depends on the objective validity of the controlled-variable experimental method" makes science "...triumphant over all earlier forms of commonsense empiricism" (p. 98). The late-nineteenth century view of scientific processes and knowledge as revealing *the truth* supported the absolute claim of scientific knowledge "...subordinates all nonscientific cognition to the inferior status of pre scientific intellectual infancy or post scientific application" (p. 99).

The late-twentieth century understanding of science and technology is that the two are different communities, but intertwined communities. Wise (1985) defined science as "...knowledge about nature, acquired for its own sake.... and ...the institutions and people who generate that knowledge" (p. 230). Technology, he defined as "...knowledge about the man-made world, generated for use, and ...the community of people (including engineers, inventors, scientists, and craftsmen) who contribute to this knowledge base" (p. 230).

In a look at these two communities, Layton described them as having different values and concerns. He saw them as mirror-image twins, having a symmetric relationship in which "...information can be transferred in either direction" (p. 578). The mirror-image results from several factors -- Whereas theory ranks high in science, doers rank high in technology; science postulates unobservables, while technology does not. Bauer (1992) adds some further examples to this mirror- image model of science and technology, displayed in Table 18.

The consensus knowledge view of science, and the view that it is not value-free, permits a new idea of the relationship between science and technology. Today, the view of science and technology as different (yet interdependent) entities influences science educators' ideas of teaching about science and technology.

All three reform movements include a need for students to understand relationships between science and technology. In Science For All Americans, scientific literacy is defined in terms of "science, mathematics, and technology." Technology is "...a complex social enterprise that includes not only research, design, and crafts but also finance, manufacturing, management, labor, marketing, and maintenance" (AAAS, 1989, p. 39). Technology has its own processes and roles as a force of change in society, a role of which scientifically literate citizens need to be aware. It has a role to play, one that may or may not depend upon scientific knowledge.

Table 18: Science and Technology

(1) Science is universal; scientific principles are the same everywhere.	(1) Technology is particular and can be very different.
2) Science has continuity over time.	(2) Technology can make sharp breaks with the past as quite different new ways of doing things replace old ways.
(3) Science is intangible, abstract, consensus knowledge.	(3) Technology is bound up in tangible things. Technology is more like creativity in art.
(4) Science is open and public. Scientists strive for recognition by publishing first.	(4) Technologists may be successful builders who keep designs a secret.
(5) The criterion for whether something gets done is different between the two. Science works best if new pieces to the puzzle are added as soon as possible.	(5) In technology, human benefit or utility is the criteria for doing something.
(6) Science cannot be controlled -- it cannot be made to deliver particular knowledge that is wanted or needed.	(6) Technology can be socially, politically or economically controlled (pp. 125-127).
(7) Scientists are members of a scientific community that worry about the community's reputation.	(7) Technologists work to satisfy their employers and themselves -- there are no strong community ties.

Some ideas presented in *Science For All Americans* about technology that are to be a part of science and technology education are:

- (1) It draws on science and contributes to it.
- (2) Technologies always have side effects.
- (3) Technological and social systems interact strongly.
- (4) The social system imposes some restrictions on openness in technology.
- (5) Decisions about the use of technology are complex (Chapter 3, pp. 39-45).

STS classes stress the role of technology in society. As the three initials indicate, science, technology, and society are major concerns of STS instruction. How the three relate, interact, influence, stimulate, and affect each other is an area of study in the classroom. Also, it becomes important in STS classrooms to investigate how society handles or is handled by scientists and technologists.

The conceptions of the nature of scientific and technological knowledge and processes and their roles in society influenced science education reform in the late-nineteenth century and still influence it in the late-twentieth century. This factor is common to and influential on science education reformers of both eras, but is very different for the two times. Social construction of knowledge replaces the training of mental faculties in the late-nineteenth century, science as consensus knowledge replaces science as truth, and science educators establish a place for technological education in today's science classrooms.

IV. Common Factors Associated With, Shared by, and Influential on The Use of the Laboratory Method in Reforming Science Instruction of the Late-Nineteenth and Late-Twentieth Centuries

The laboratory approach to teaching science was *the new* instructional method of the late-nineteenth century. From primary grades through secondary school, science educators pushed for the use of the *best* method of instruction, the laboratory approach (Table 7). The desire for laboratory experimentation played a big part in reform ideas of late-nineteenth century science education.

The laboratory maintains an important status in instructional processes of today's reform movements. The laboratory is a part of the total science curriculum, Table 19. It is not separated and isolated from the rest of the activities of the classroom, but rather is an integrated part of the class. No longer are laboratory experiences to be only affirmations or illustrations of scientific concepts, laws, or theories, as was the purpose of the laboratory in the late-nineteenth century, but student initiated interest and questions serve as a guide to laboratory work in today's reformed classrooms.

The late-twentieth century high school science classroom, in theory at least, appears to be more student-centered. Some of the cries of late-nineteenth century science educators are finally being heard. "Teach what is relevant." "Start with the concrete and then move to the abstract." "Go from the known to the unknown." "Put the object of study in every student's hands." "Study nature that is nearest." "Start in the schoolyard." (Dryer, 1888; Jordan, 1890; Jackman, 1894).

Table 19: The Role of the Laboratory in Late-Twentieth Century Science Education

Name	Role of Laboratory
STS	To study real-life, personal, societal science and technology problems; promote group learning - discuss approaches to problems; Problem solving situation.
Project 2061	To get acquainted with things around them-- including devices, organisms, materials, shapes, and numbers.-- to observe, collect, handle, describe, and become puzzled by things; to ask questions, argue, and try to find answers; Start with questions about nature; engage students actively-- collecting, sorting, cataloging, observing, note taking, dissecting, measuring and counting; use a team approach; do not separate knowing from finding out.
SS&C	Provide hands-on experience with phenomena before terms are defined or concepts named. First develop through experience the concepts that are related to facts -- then conduct or read about careful investigations-- examine the results and arrive at relationships through own analysis.

Student activity is all important in today's science classes. Students must have in their hands the objects under study, whether it was in the late-nineteenth century or is in the late-twentieth century. Today the concept of what can be done and what counts as laboratory experiences are different. Student activity in the laboratory consists of groups discussing research questions, data, or issues relevant to them. In the late-nineteenth century the laboratory produced verification of the truth; today, it produces questions.

The desire of science educators, in both times, to include laboratory instruction or hands-on experiences for students, resulted in goals for greater and newer uses of laboratory instructional methods. This common desire influenced the directions of science education reform efforts in both eras. The underlying theories of the nature of science and the prevailing learning theories of the day, helped to shape the reforms called for in the use of the laboratory method of instruction in schools, and as a result of this initiative on the part of reformers, science laboratory instruction has a different look in the two eras under study.

V. Common Factors Associated With, Shared by, and Influential on the Reform Efforts of Science Education in the Late-Nineteenth and Late-Twentieth Centuries

Education, by the beginning of the twentieth century, had become, in theory at least, an education for all. Science education was to fit the common man for his place in the highly scientific and technological world in which he lived. Reforms under way today, as described by Project 2061, STS, and SS&C, reflect similar aims. The reform

recommendations and suggestions made by reformers of both times reflect many of the ten common influential factors identified at the beginning of this chapter.

The previous sections, in examining the role of these common factors on perceived problems, goals and aims, the philosophy of science and the psychology of learning, and the use of the laboratory method in science education, pointed out some of the wishes and hopes of science education reformers in both eras.

In this section the author examines some of the specific recommendations of the major reform organization of the late-nineteenth century, the Committee of Ten, and the major reform organizations and initiatives of the late-twentieth century, STS, 2061, and SS&C.

1. Recommendations of the Committee of Ten:

A list of some of the major recommendations for the teaching of science made by the different science conferences of the Committee of Ten includes the following;

- (1) Science instruction calls for the use of laboratory methods of instruction, primarily through the techniques of observation and induction.
- (2) Science instruction should not wait until the secondary school, but should begin as early as the primary grades.
- (3) Science study should begin with the study of simple natural phenomena in the grades.
- (4) Science teachers need better training at all grade levels, particularly in the laboratory method of instruction.
- (5) Science instruction should occur through observation of natural phenomena, with the object in the hands of students.

- (6) Science courses should be taught the same for all students enrolled in a particular class, whether they were going to college or not.
- (7) Science should be included as a course necessary for college admission. Admissions tests should consist of both a written and a practical examination. The laboratory notebook should serve as a reference for admission to college.
- (8) Botany, zoology, chemistry and physics should be the order in which the courses are taught.*
- (9) Human physiology should be a non-laboratory, informational course, primarily taught in the upper grades.

The following review of the reports of the three science conferences presents each conferences' recommendations about science instructional reform in their field in 1892-1893.

A. The Physics, Chemistry and Astronomy Conference Report: (NEA, 1893, pp.117-137)

The Physics, Chemistry and Astronomy Conference spoke of " ...training the faculties to make accurate observations and to draw safe inferences...." They viewed observational processes and skills as the foundation for forming inferences, "...[T]he inference based upon complete observation is more simple and more sage than that based on other inferences"(p.122).

The summary report of the Physics, Chemistry and Astronomy conference described the importance of the laboratory in science education at all levels of schooling, -- "...from

* There was some disagreement with this order of courses. Some educators felt that physics should precede chemistry. This disagreement still continues in 1993.

the beginning the study [of science] should be pursued by the pupil chiefly, though not exclusively, by means of experiments and by practice in the use of simple instruments for making physical measurements." Statements such as, "study of things and phenomena by direct contact," "emphasize a large proportion of laboratory work in the study of physics and chemistry," and the "conjoining of laboratory work with the text, lectures and demonstrations," show the importance placed upon the new laboratory method of teaching science (NEA, 1893, p. 26).

This conference described the ideal situation as one in which students carried out experiments, but stressed that "...an intelligent teacher to aid the student in interpreting the statements of the book and the phenomena observed, as well as to show him how to work" was a very important factor. The Conference reported that the "...mere performing of experiments in a laboratory...", however well equipped it is "...cannot accomplish what is desired..." without the intelligent teacher there to guide the students (p. 119).

The conference also pointed out that good science teachers, skilled in the laboratory method of instruction were hard to find and recommended that special science teachers or superintendents be appointed to instruct "...teachers of elementary schools in methods of teaching natural phenomena" (p. 117).

This report carried with it a list of 50 experiments in physics and 100 in Chemistry. Irving W. Fay of The Belmont School, Belmont, California, and G.W. Krall of the Manual Training School, Washington University, St. Louis, Missouri prepared this list of experiments. The physics experiments were of the type that primarily confirmed and/or made measurements of objects, such as:

- (1) Find the volume, weight and density of several solids
- (2) Pressure of liquids as to direction and depth

(3) Relation of pitch to length of wire and

(4) Mapping the lines of magnetic force for a bar-magnet.

The chemistry experiments mainly dealt with the properties of different elements, basically a descriptive approach to chemistry. For example:

(1) Contact and chemical change

(2) Properties of oxygen with sulphur

(3) Properties of oxygen with phosphorus

(4) Preparation of hydrogen

(5) Properties of Hydrogen

(6) Preparation of nitric acid, etc.

Astronomy received little recognition in this report. The main thing the conference recommended about astronomy was that it should be taught by observations as well as classroom instruction and that it not be included as a science for college admission.* (p. 118).

B. The Natural History Conference Report: (NEA, 1893, pp. 138-161)

The conference on natural history included botany, zoology, and physiology. It assigned each of these courses an important role in high schools. Botany, since it required "less specific circumstances" and had less impact on the sensitivities and prejudices of

* It is perhaps noteworthy here to realize that astronomy soon began to be omitted from the high school curriculum. The fatal blow to astronomy in the high school program was that it was not included as one of the required sciences for college admission.

students than did zoology, became the introductory science course in high schools. Zoology followed botany, then chemistry, with the last years of high school science including physics and physiology. Physiology required physics and chemistry for a thorough understanding and therefore was put off until later in the high school career.

The conference recommended that the study of natural history proceed "...by direct observational study with the specimens in the hands of each pupil" (p.141). The main type of observational method used and stressed in botanical work was drawing. Drawing was "...not only ... an excellent device for securing close observation, but it [was] also a rapid method of making valuable notes" (p. 152). The committee almost banned the use of a textbook so that the study would occur through the direct observation of nature. The only books they recommended were those to be used as laboratory manuals or as books of reference (p.151).

In both botany and zoology, the amount of time spent in laboratory activities far outweighed the time spent in lecture or recitation. For botany, the conference recommended that three out of five days a week be devoted to laboratory work, with one day for lecturing and one day for quizzes. In zoology they recommended that a total of 120 hours out of the total 200 hours of class time be for laboratory research. Laboratory reports and text-book work made up the remaining 80 hours of class time.

Physiology presented a different situation than either botany or zoology. Because of the nature of the topics in physiology, human anatomy, hygiene, etc., this was the only course among all of the sciences in which the conference did not recommend laboratory work over text-book work. The nature of the subject matter limited the use of the laboratory approach in the high school. Physiology became an informational, disciplinary science rather than a laboratory one. Its purpose as a subject in high school was primarily for its "...practical relations to personal and public hygiene" (p.160).

C. The Geography Conference Report: (NEA, 1893, pp. 204-249)

The geography report, which really seemed to take seriously an innovative approach to its recommendations, also supported the laboratory approach. Geology, the conference reported, should be "practical instruction in the field" and meteorology should begin with "local observations of the passing weather changes." The conference described its philosophy of education as "...first see; next reproduce; then study the productions of others, and meanwhile, ponder and reason on all" (p. 211).

They put the same stress upon observation and reasoning powers as did the other sciences. The role of geographical sciences was to "develop the power and habits of geographical observation" (p.211). Observation of the natural world, directly by the pupils, was a primary concern of this group as well as the training of the mental powers involved in working in scientific endeavors.

The Conference on Geography recognized many different scientific disciplines included under its domain. They included geology, meteorology, physical geography and even overlapped into other main branches of science to some extent. This was one of the more innovative science conference reports. They expressed an interdisciplinary view of their subject -- including such things as drawing, history and English connections (NEA, 1893, p.33).

D. The Committee's Summary Report: (NEA, 1893, pp.1-59)

Principles of mental discipline and the laboratory approach to teaching science guided the recommendations for science instruction made by the Committee of Ten in 1893. An examination of the final Report of the Committee of Ten elicits a type of science very reminiscent of Charles Eliot's scientific pedagogy; science not as informational textbook science, but one involving actual contact with materials of nature.

Dr. Eliot played a major role in the formation of the conferences and in the general attitude with which the committees approached science education. He envisioned a new way of teaching science and became instrumental in initiating his ideas at both the college and secondary levels.

Instruction occurred through the senses, through hands-on methods, through the "seeing eye and the informing fingers" (Eliot, 1905, p. 6). All science instruction focused on the laboratory and the use of the inductive approach. The general report stated that all the science committees "...dwell on laboratory work by pupils as the best means of instruction, and on the great utility of the genuine laboratory notebook..." (NEA, 1893, p. 18).

Changes in society began to affect schools and the newly published report of the Committee of Ten faced challenges. Some of the same social forces, some new ones, and some different concepts about old ones, pushed for changes in the schools. However, the laboratory method of science instruction maintained its position as "the" method of science education, even until 1993.

The recommendations of the Committee of Ten can be summed up in the words *laboratory method*. All sciences, at all grade levels, (except physiology) were to be taught with experimentation and the real object under study in the hands of the pupil. The ultimate aim of secondary science instruction was not preparation for college or factual knowledge, but empowerment of the individual. Through the use of scientific processes in everyday life, individuals had the power to deal with and face any situations that life presented to them. The democratic society, of which students were a part, needed individuals who could think and act with scientific habits of mind.

The periodical literature of the day contained recommendations for good science teaching made by other late-nineteenth century educators who were not a part of the

science conferences of the Committee of Ten. Table 20 presents an overview of some of the suggestions these educators made concerning science instruction. In most instances their ideas were similar to those presented by the Committee of Ten, but in some cases their visions were broader than those of the Committee.*

Whereas the Committee of Ten kept the sciences separated into different logical classifications, some of the other educators (Martin, 1888; Yonce, 1888; Beach, 1896; Boyer, 1897; Richardson, 1899) of this time voiced ideas about the interdisciplinary nature of science. The Geography Conference was the only science conference in which ideas of the interdisciplinary nature of science arose.**

2. Recommendations for Secondary School Science Made by Late-Twentieth Century Reform Movements:

The strongest recommendation made by all three reform movements today is the education of *ALL* students in science. All students are to have the opportunity to succeed

* Eleven questions guided the discussion of the various science conferences in their suggested recommendations, and most of these conferences kept their discussions in line with these questions. These questions, to some degree, served as a stifling factor to more creative approaches to science teaching. The educators cited in Table 20, had no such questions to direct their recommendations, but were free to suggest more innovative ideas.

** Perhaps as an outcome of Francis Parker being a member of the Geography Conference and the fact that the conference convened at Parker's school, Cook County Normal School, the committee's ideas may have been influenced by his views of nature study being at the center of all other disciplines.

Table 20: Some Late-Nineteenth Century Science Educators' Ideas of Reforms Needed

Name	Reform Needed	Name	Reform Needed
1887 Lewis	Experimentation by pupils or teachers; New methods of teaching to incite pupil to mental and manual activity.	1893 Nelson	Have fewer subjects and better instruction.
1887 Rappleye	Use of real things; lab work.	1893 Clapp	Begin with where the child is; Best presentation of a thing is the thing itself; Use things simple to the child.
1888 Martin	No specialization of courses.	1893 Rice	Teachers guided by laws of mental development.
1888 Dryer	Work with hands; Specimens in hand; Use class discussion; Study what is nearest first; exams should be practical problems.	1895 Harris	Supplementation with experimental work on part of teacher and pupils.
1888 Ballard	Experiments by pupil; Study what's around students; well-trained teachers; memorize nothing from book.	1895 Jackman	More experiments in grades; field work; science in the grades below the high school.
1888 Morrison	Inspire desire to know; good teachers; experiments by pupils.	1895 LeConte	Use of newer methods of Laboratory and field work. Teach what can teach the best.
1888 Koyl	Use of lab method.	1896 Weed	Lab method only adequate way to study biology.
1888 Yonce	Show relationships between sciences; encourage inquiry by pupils; teacher who knows science; use practical illustrations.	1896 Paddock	Close gap between teaching of science in high school and the practical applications outside the school.
1888 Morrill	Experimentation by pupils; keep notebook; go from known to unknown.	1896 Beach	A spiral method of teaching by which the range of subject grows gradually higher and broader, coming back to the same thing again and again.
1888 Zartman	Reduce number of courses taught; use laboratory method; teach science practically; good teachers.	1896 Jackman	High school lab should deal more with the experiences of the pupil; lab should be a place where the student finds answers to the questions in his mind.
1889 Clarke	Include natural science in primary and throughout all school years.	1896 Gage	Teachers and pupils work together-- see teachers as elder brothers.
1889 Allen	Science courses for all students; use lab; start with questions from teacher and pupil.	1897 Boyer	All lecture based on lab and field study; recognize no distinct boundaries between sciences.
1890 Harris	Student experimentation; study of natural sciences early in school.	1898 Hay	Must study biology in the lab or field; students find out for themselves and help of teacher and books.
1890 Jordan	Teach what you can teach best; Use good books; Allow nothing to come between the pupil and the object he studies.	1899 Richardson	The ideal course of experimental science for secondary schools is one that makes no effort to keep them differentiated, but, rather unites in one course as much of both as is needed to gain a thorough understanding of the phenomena studied.

in a science education program that results in scientifically literate citizens for the scientific and technological world of which they are a part. Science education is an education needed for the general public and not geared specifically for the college bound. Regardless of background or destination, all Americans need to be literate in scientific and technological aspects. Each reform has its own ways to accomplish this goal, Table 21.

A. Science/Technology/Society:

STS advocates view their model as an answer to current concerns in science education. "STS education aims to promote scientific and technological literacy in order to empower citizen participation in democratic decision-making and action processes for resolving the pressing, technologically-dominated problems of our late industrial society" (Waks, 1989, p. 201).

Through the involvement of students in problems or issues or situations that are personally and socially relevant, such as world hunger, disease (AIDS), over-population, genetic engineering, depletion of natural resources, air and water pollution, and destruction of the ozone layer, they learn scientific principles. Students realize the importance of basic concepts and processes needed to solve problems at hand (Yager, 1991a). Therefore, content, processes, and attitudes learned by students in an STS program result from interactions in group or classroom investigations.

Issues, problems, and/or situations investigated either stem directly from students themselves or, most likely, from problematic/issue situations provided by teachers. Students determine what it is that they need to know in order to solve problems or understand issues, and then devise their own group/class activities and plans based on their stated goals.

Table 21: Suggested Reforms by Late-Twentieth Century Movements

Reform Movement	Suggestions
STS	Students actively involved in relevant problem-solving and decision making situation; Use of student ideas and questions to guide lessons; group activities; focus on the impact of science on each student
Project 2061	Science literacy for all students; a common core of learning; interdisciplinary in nature; decrease use of textbooks; depend more on class discussions and investigation; teachers as professionals; Less is More; use of scientific knowledge for <u>social and individual purposes</u>
SS&C	Developments of a carefully sequenced, well-coordinated curriculum in all sciences that all students study every year for seven years so that students acquire a greater depth of understanding in science.

The goals of STS instruction reveal the relationship of students to the real world. *Project Synthesis*, formulated four cluster goals that also define the STS initiative. These goals are:

- (1) *Science for meeting personal needs.* Science education should prepare individuals to use science for improving their lives and for coping with an increasingly technological world.
- (2) *Science for resolving societal problems.* Science education should produce informed citizens prepared to deal responsibly with science-related societal problems.
- (3) *Science for career awareness.* Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.
- (4) *Science as preparation for further study.* Science education should allow students who are likely to pursue science academically, as well as professionally, to acquire the academic knowledge appropriate for their needs (Yager, 1991a).

In STS instruction, students have ownership of the content and some control over the curriculum. The emphasis in STS is on the learner as an active participant in the learning process, and learning outcomes are "...an interactive result of what information is encountered and how the student processes it based on perceived notions and existing personal knowledge" (Yager, 1991b, p. 53). Engaging in focused play, brainstorming, looking for information, experimenting with materials, observing phenomena, designing

models, collecting and organizing data, using problem-solving techniques, discussing solutions with others, evaluating, analyzing, defining, and debating are all types of explorations found in an STS class (Yager, 1991b, p. 55). STS is not proposed as a curriculum, but rather as a model of teaching capable of use at any grade level.

B. Scope, Sequence and Coordination:

Like other reform movements, *Scope, Sequence, and Coordination*, proposed by the *National Science Teachers Association* (NSTA), realizes that the current layer-cake curriculum is not working. Their answer is basic science. SS&C advocates "...presenting key science concepts, appropriately sequenced, manageable in their scope, and coordinated within and between the science disciplines" (NSTA, 1992a, p. 15).

Each of the three terms in the project title defines an aspect of the reform movement. *Scope* is topics, themes, theories, laws, principles, and concepts of science included in the curriculum. *Sequence* is development of curriculum from a psychological foundation, beginning with experience-based concepts and progressing to higher levels of abstraction. Finally, *Coordination* involves a well-coordinated approach to four distinct sciences; biology, chemistry, physics, and earth/space science.

Each science discipline is to be taught each year, for seven years, in grades 6-12. These four separate sciences are coordinated through some theme, such as those provided by Project 2061. Through different course designs, such as "Great Ideas of Science" or "Phenomena" or "STS" or "Disciplined-based courses," SS&C tries to provide some frameworks from which curriculum designers produce their own types of courses (NSTA, 1992a, pp. 19-25).

The basic science approach depends on foundations of constructivism and hierarchies of learning. SS&C bases its curriculum designs on the following learning statements:

- (1) Spacing Content Improves Learning
 - (2) Learning is Not Improved by Ability Grouping
 - (3) All Students Can and Should Learn Science
 - (4) Students Learn by Practice--Solving Problems, Designing and Carrying Out Experiments
 - (5) Learning is Connecting New Information to Prior Knowledge
- (NSTA, 1992b).

SS&C is a spirally arranged curriculum with each successive year presenting higher levels of abstractions about principles, laws, and theories. The basic science approach incorporates taking students from what they already know, to abstract conceptions about science through experiences in the science classroom. Over a period of years, experiences with concrete objects evolve to manipulations of ideas and abstractions as students construct their own knowledge based on personal experiences.

C. Project 2061

The more far reaching of the current science education reforms is that of the *American Association for the Advancement of Science (AAAS)*. In response to the question posed by Project 2061, *What knowledge, skills and habits of mind associated with science, mathematics, and technology should all Americans have by the time they leave school?* the National Council on Science and Technology Education recommended

four types of knowledge bases necessary for secondary students to possess at the end of their schooling. These four recommendations include knowledge about things such as:

- (1) The nature of science, mathematics, and technology -- collectively, the scientific endeavor -- as human enterprise.
- (2) The world as currently seen from the perspective of science and mathematics and shaped by technology.
- (3) Some of the great episodes in the history of the scientific endeavor and about some crosscutting themes that can serve as tools for thinking about how the world works.
- (4) Some of the habits of mind that are essential for scientific literacy (p.19).

In an effort to address these recommendations, Project 2061 reformers engage in a long term investment designed to produce science for *all* Americans in grades K-12.* Science educators involved in this reform movement envision in Project 2061 a special kind of science education, one in which the development of "...understandings and habits of mind..." needed to "...become compassionate human beings able to think for themselves and to face life head on" occurs (AAAS, 1989, p. 12). Project 2061 recognizes scientific literacy as a "central goal of education" (AAAS, 1989, p.11).

Main tenets of Project 2061 incorporate ideas of both STS and SS&C, plus more. Project 2061 is a major proponent of the *less is more* philosophy of science instruction and suggests that schools need to "focus on what is essential to scientific literacy and to

* The title, *Project 2061*, emphasizes the long term commitment that is envisioned by its directors; 2061 comes from the year of the return of Halley's comet.

teach it more effectively" (AAAS, 1989, p.4) In order to do this, Project 2061 leaves out some of the content in current curricula and puts more stress on others.

Examples of what is left out:

- (1) Rigid boundaries between traditional disciplines,
- (2) Topics that lead to specialization such as series and parallel circuits, genetic transcription mechanisms or
- (3) Topics that pose more difficulty than is reasonable such as the periodic table of elements, Krebs metabolic cycle, or quadratic equations and
- (4) Too much technical vocabulary such as endoplasmic reticulum, ribosomes.

Examples of what is included:

- (1) Organization of content by aspect of the world, such as the living environment;
- (2) Common themes that stimulate thinking across all sciences, such as systems, constancy;
- (3) Explicit connections among science, mathematics, and technology that relate to their human and social aspects; and
- (4) The "big picture" in common English rather than all the supporting details and specialized vocabulary (AAAS, 1992, p. 4).

In order to accomplish the *Less is More* approach to science, AAAS recommends the softening and connecting of traditional boundaries between subject areas and the emphasizing of ideas and thinking skills. One curriculum design, one textbook model, or one teacher-proof method, does not limit the long range goals of Project 2061. ✓

The project recognizes the need for effective learning and teaching. For effective learning to take place, reformers in Project 2061, much the same as in STS and SS&C, realize the importance of active participants, active students involved in doing such as "...collecting, sorting, and cataloging, observing, note taking and sketching; interviewing polling, and surveying; and using hand lenses, microscopes, thermometers, cameras, and other common instruments" (AAAS, 1989, p. 147).

The influence of pre-existing ideas, the progression from concrete to abstract, practice of learned concepts in new situations, feedback, and challenging teachers are all important components of the reform movement (AAAS, 1989). Principles of learning upon which Project 2061 is based are:

- (1) Learning is Not Necessarily on Outcome of Teaching
- (2) What Students Learn is Influenced by Their Existing Ideas
- (3) Progression in Learning is Usually from the Concrete to the Abstract
- (4) People Learn to Do Well Only What They Practice Doing
- (5) Effective Learning by Students Requires Feedback
- (6) Expectations Affect Performance (AAAS, 1992, p. 32).

Project 2061 takes into its reform efforts science instruction in the elementary schools as well as in the secondary schools. It is a K-12 initiative that strives for "...good teaching throughout 13 years of school" (p.20).

Those involved in elementary education recognize that science is a necessary part of decision-making skills needed by citizens of the late-twentieth century and the coming twenty-first century. Loucks-Horsley, et. al. (1990) presented views of current reform efforts for elementary science education when they noted: "We need to ensure that science

is an important part of children's educational experience" (p. ix). These authors see science education as a means of developing skills in observing, explaining, reasoning, and making informed decisions (p. ix-x). Each of the thirteen chapters of their book, *Elementary School Science for the '90s*, is a recommendation about science instruction. They are as follows:

- (1) Make Science a Basic
- (2) Build Curriculum that Nurture Conceptual Understanding
- (3) Connect Science to Technology
- (4) Include Scientific Attitudes and Skills as Important Goals
- (5) View Science Learning from a Constructivist Perspective
- (6) Use a Constructivist-Oriented Instructional Model to Guide Learning
- (7) Assess What is Valued
- (8) Connect Curriculum, Instruction, and Assessment
- (9) Use a Variety of Assessment Strategies
- (10) Assess Programs as well as Students
- (11) View Teacher-Development as a Continuous Process
- (12) Choose Effective Approaches to Staff Development
- (13) Provide Teachers with Adequate Support to Implement Good Science Programs

The concept of science for all, the use of constructivist principles of learning, and a child-centered approach to science instruction, presented in their book, embodies the visions of Project 2061 at the elementary level. Other reform efforts also incorporate the goals and principles of Project 2061 into their agendas. One such use of Project 2061's

tenets is that by The National Committee on Science Education Standards and Assessment. Using ideas and recommendations of Project 2061, this committee seeks a means of establishing national science standards.*

VI. Summary

The late-nineteenth century's cries for teaching more about less, educating students to develop scientific habits of mind, empowering individuals to face everyday life situations, studying first those things close by, putting nature into the hands of every pupil, doing away with memorization of terms, and the study of one thing through the various sciences, echo in the calls for reform in the late-twentieth century.

So, are reforms of the two decades before the turn of the two centuries really as similar as they seem? The answer to this question is both yes and no. There are common factors that influence and guide the ideas about reform in science education in both eras. The author, in chapters two and three, discusses ten of these factors in association with science education in the late-nineteenth and late-twentieth centuries. These ten elements play a role in reform recommendations made by each era, and because of the common factors that influence the direction of science education reform, the ideas and concerns of

* As a result of these three science education reform movements, as well as presidential and gubernatorial outcries for better science instruction and scientifically literate citizens, there is also a national standards movement underway. The National Research Council, in 1991, set about identifying goals for science education that can serve as national standards. Their main areas of concern are: (1) science curriculum standards, (2) science teaching standards, and (3) science assessment standards (p. 6). The National Science Education Standards "...will not prescribe particular courses, programs of study, or textbooks; assessment standards will not be a set of examinations; teaching standards will not be certification or licensure specification" (NRC, 1993, p. 5). The job of this council is to come up with standards in science education that will provide "Overarching goals and criteria...and examples to illustrate the range of what is possible, not define the one 'best' approach" (p. 5). The premise for this program is that *ALL* students, not just Americans, can and should learn science.

both eras appear similar. However, there are differences in some of these factors between the two eras, and it is these underlying differences of the common factors that cause reform movements of both eras to be somewhat different, but yet appear to be much the same. A discussion of these common factors, their similarities, differences and influence on science education reform, is part of the following chapter.

CHAPTER 5

SUMMARY: CONCLUSIONS AND RECOMMENDATIONS

So the next year, when I came into physics lab, I found that Mrs. Cramer had been given a two-month summer education course in physics teaching...She had all sorts of teachers' guides to help her, and physics manuals detailing the classic formulae and problems. I imagine she went home every night and tried to memorize the next day's answers. But it just didn't work -- she found that when she tried to do a black board problem for us best she could, the result didn't agree with the answer she'd memorized. So she'd wipe out her answer and substitute the one in the manual, and tell us that even if she hadn't gotten the equations straight, this was the proper answer, and we should memorize it. When she gave tests, they never called for any problem calculations. They simply stated the problem and left a blank space for the proper answer....She never learned ...that the chemical symbol for mercury wasn't Mk. It wasn't funny; it was pathetic (Budrys, 1960, pp. 79-80).

Thank goodness this is a fictionalized account of a high school physics class!* Unfortunately, this could possibly be a description of some high school physics class today. This fictionalized account gives a picture very similar to the real situations

* This description of a high school physics teacher is found in *Rogue Moon*, a science fiction story, by Algis Budrys. The setting was Earth, 1959 and is the description given by a scientist, Hawks, about his school science experiences.

described by Jordan (1890) at the beginning of chapter one. Both of these quotations describe teaching as a way to get students to memorize answers from textbooks. As this study has shown, memorization of the *correct* answers appears to be the result of much science instruction, in the late-nineteenth century as well as now. Maybe one cannot compare fact and fiction, but data presented in chapter three concerning teachers' uses of instructional methods reveal that this fiction may be closer to the truth than some would like to admit (Table 12).

In response to this type of classroom teaching, reformers (of either era) present their ideals and aspirations in hopes for something better in classroom science instruction. It was the similar recommendations made by science education reformers of the two different eras that suggested this study and the questions; *Are there common factors that help initiate and direct the calls for reforms? What can history tell us about the reform processes? What can we learn from previous experiences with similar reforms?*

The author has identified some factors common to and influential on late-nineteenth century and the late-twentieth century reform ideals, and has shown that some underlying differences in these factors in the two different eras made their effects on reform ideals somewhat different, while at the same time appearing very similar.

Figures 7, 8 and 9 depict how these common factors filter through the times of the late-nineteenth and late-twentieth centuries, and result in similar, but at the same time, somewhat different ideals about science education reform. This is probably as one would expect it to be, for changes have occurred in science education from one hundred years ago. Science instruction in today's schools is much better than what occurred one hundred years ago. Today's science classes exemplify some of the ideals of late-nineteenth century science educators, but as the times change so do the conceptions about the ideals of science education, and therefore continued reform is necessary.

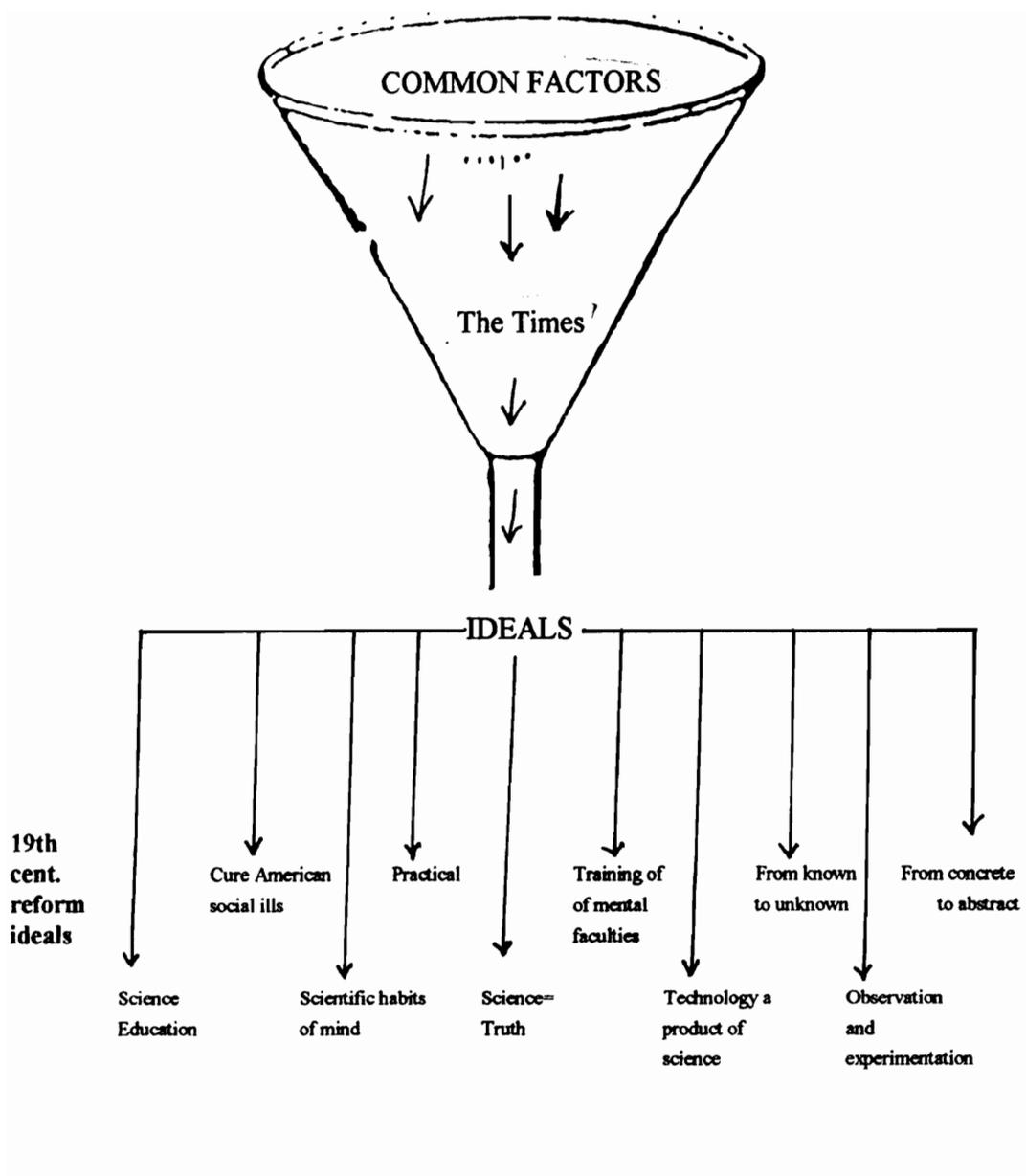


Figure 7: Common Factors and Their Influences on the Ideas and Direction of Late-Nineteenth Century Science Education Reform

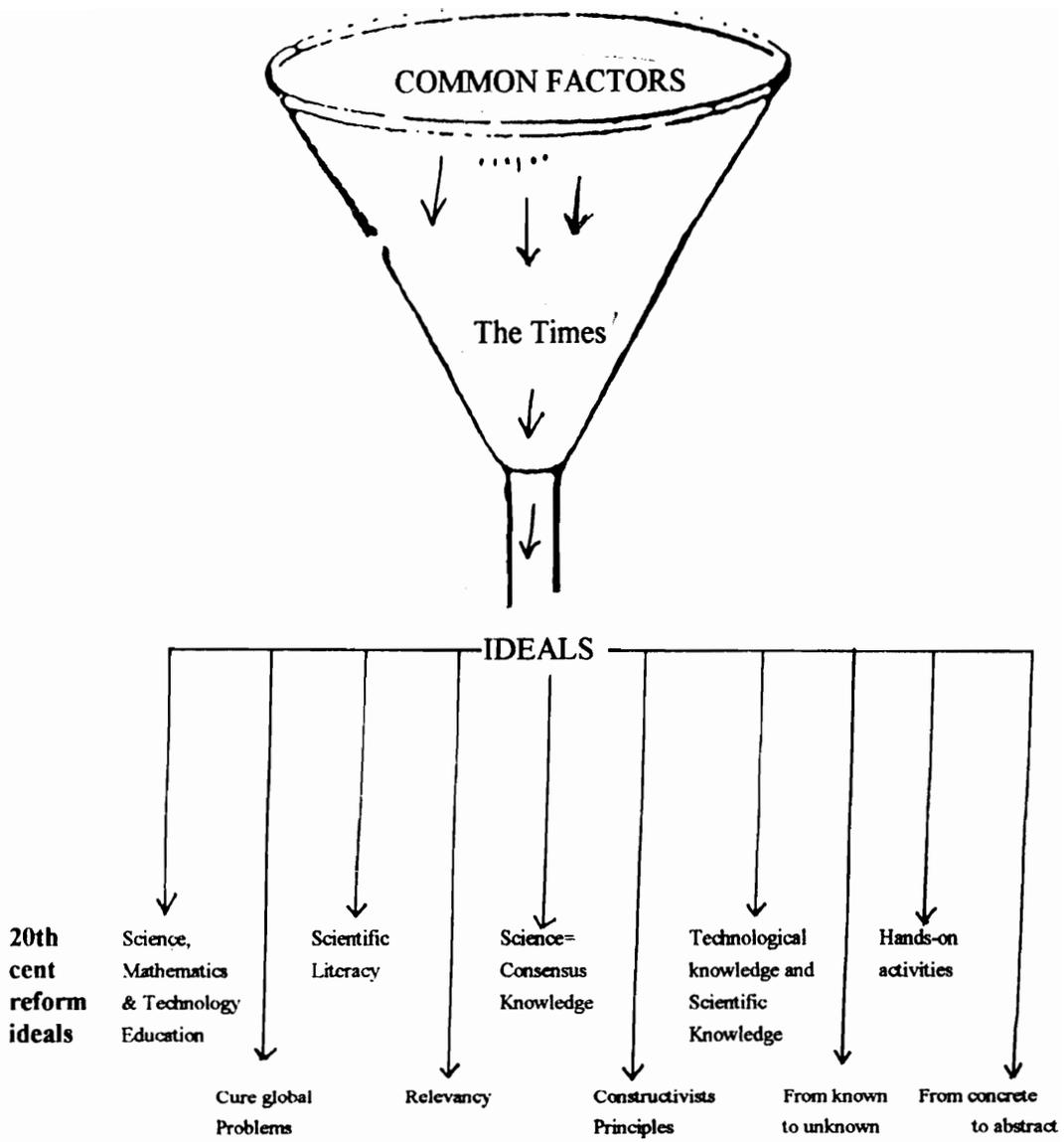


Figure 8: Common Factors and Their Influences on the Ideals and Direction of Late-Twentieth Century Science Education Reform

Common Factors

Late-Nineteenth Century Ideals of Science Education

Late-Twentieth Century Ideals of Science Education

Cure American Social Ills

<----->

Cure Global Problems

Practical

<----->

Relevancy

Science instruction

<----->

Science, mathematics and technology instruction

Scientific habits of mind

<----->

Scientific literacy

Science = Truth

<----->

Science = consensus knowledge of a community

Training of mental faculties

<----->

Constructivists principles of learning

From known to unknown

<----->

From known to unknown

Technology a product of science

<----->

Technological knowledge and scientific knowledge

From concrete to abstract

<----->

From concrete to abstract

Observation and experimentation

<----->

Hands-on activities

Figure 9: Diagram Showing the Relationship of the Differences in Science Education Ideals Brought About By the Filtering of Commonly Shared Factors Through the Different Time Periods of the Late-Nineteenth and Late-Twentieth Centuries

In the section to follow, the author summarizes six conclusions about some of the ideas gained from an examination of reform efforts. These conclusions point to some of the similarities between the reform movements and at the same time show how the movements differed.

I. Conclusions

1. Striving for ideals:

Reformers of science education strive for ideals influenced by social, political, economic and educational conditions of the age.

This study shows that reform movements strive for the *ideal*. Ideals are positive aspects of reform movements that provide goals with which reformers attempt to make science education better. Educational reform incorporates the visions and dreams of educators of an era into those ideals they see as the best means of instruction, curricular content, or arrangement.

The author, in chapters two and three, discussed some factors that served as forces that affected the ideals of an era. It was shown that many times, reform ideals of an era are overcast with ideas pertaining to international competition, economic and national security, preservation of the hegemony or the disempowerment of teachers (Shymansky & Kyle, 1992). Other things, such as the prevailing educational philosophy of the day, the conception of science, and the need for scientifically literate citizens were shown to play a role in science education reform.

Conditions found in society influence the social, economic, scientific and technological agenda of today's reforms (Anderson, 1983, 1992; Kyle, 1991; Cuban, 1990a). The failing economic and academic standings of the United States bring attention to the role of science and technology in today's society (Cuban 1990a; Raizen, 1991; Apple, 1992). In answer to the perceived scientific and technological illiteracy of the American people, science educators are responding with a call for the education of **all** Americans in a common core of learning about science and technology. "The current passion among states for a traditional education, one in which every student studies a core of academic subjects, is one example of a recurring solution dating back over a century....a solution to the problem of how to balance societal values of excellence and equity..." (Cuban, 1990b, p. 135).

In times of extreme social disparity, some late-nineteenth century educators concerned themselves about the welfare of the republic (Jordan, 1894; Eliot, 1898; Crowe, 1900). In a democratic society, the good of society depends upon the skills of **all** citizens, and for any scientific era, part of those skills are scientific processes. In the last decades of the nineteenth century, "...the concept of equality mandated that the conditions of schooling be the same for all" (Cuban, 1990b, p. 136). The report of the Committee of Ten supports this claim. With a return to the ideals of equality in science education today, again the concern and need arises for the education of all students in a common core of knowledge about science and technology.

In highly scientific and technological times, the future seems to lie in a different understanding of the world -- a scientific and technological understanding. Henderson (1896) described educational reforms as an attempt to bring the "...educational process once more into harmony with the *Zeist-Geist* "...to sweep away customs and practices that were never wise, and to transform those which were founded in right reason into

more modern and available form" (p.488). The ideal of creating students with scientific habits of mind and the ideal of preparing ALL students in science are apparent in both the late-nineteenth century and the late-twentieth century, but an ideal that today has been transformed into *more modern and available form*.

The late-nineteenth century was a time of great technological innovations, likewise, the late-twentieth century is experiencing what many refer to as a *revolution* in computer technology. Science education reformers of both eras felt the need for science instruction to be a necessity for students in the scientific and technological ages in which they lived. Shymansky and Kyle (1992) suggested that when changes in society, science, and technology occur, then there is a necessity to question the purposes of schooling.

Late-nineteenth century science educators questioned the traditional, impractical classical instruction typical in their schools and pushed for the inclusion of practical courses such as science. Late-twentieth century science educators question the impractical textbook science taught in most schools. The ideals of science education change with cultural influences of the times. Shymansky and Kyle (1992) noted that even if all of the reforms of the past had worked, there would still be a need for reforms in order to address our current issues and concerns (p.757).

Sarason (1990) said that even though the time is right for some ideas, there is no guarantee that we can capitalize on them because implementation requires an understanding of the settings in which these ideas must take root (p. 99). As shown in an earlier chapter, the settings in which late-nineteenth century schools existed were not the best. Overcrowding, poorly prepared teachers, lack of equipment, and lack of guidance, described the conditions of these schools. The introduction of new methods of teaching and new subjects to teach had many obstacles to overcome in order to reach the ideals recommended by reformers. Many similar settings exist today, particularly in inner-city

schools, and reform efforts have many obstacles to overcome, just as they did in the late-nineteenth century. An educational system, immersed in a society with many problems, experiences numerous and constant changes, therefore reforming science education must be a continuous process in order to meet the changing ideals of the time.

It has now become important that global relationships between science, technology and society become part of students' science education. Kyle (1991) said that science educators need to be aware that societal issues related to science and technology are no longer bounded by national borders. He said that "...it is clear that the present generation of students is the first to be faced with decisions that may determine whether the planet their children inherit will be habitable" (p. 406).

2. Similar Jargon:

Reformers of both eras use similar phrases and terms to describe their ideals of science education reform, although these ideals exhibit some differences.

Descriptions of suggested reforms for science classes made by late-nineteenth century educators (taken from Table 19), include such things as:

- (1) Start with things around the students.
- (2) Teach what is relevant.
- (3) Do not separate the various branches of science -- start with one thing and teach all sciences in light of this.
- (4) Proceed from the known to the unknown; from the concrete to the abstract.
- (5) Put nature in the hands of all students.
- (6) Do not depend upon the textbook -- depend upon nature.

- (7) Do not teach dogmatically.
- (8) Do away with memorization of terms and definitions.
- (9) Inspire the desire to know.
- (10) Have well qualified teachers.
- (11) Develop scientific habits of mind for the betterment of selves and society.

Descriptions of suggested reforms for science education made by late-twentieth century educators (taken from Tables 1 & 20), include such things as:

- (1) Have students actively involved on things and phenomena that concern them.
Focus on the impact of science on each student.
- (2) Teach what is relevant.
- (3) Use an interdisciplinary approach.
- (4) Proceed from the known to the unknown; from the concrete to the abstract.
- (5) Provide opportunities to study real life.
- (6) Decrease the use of textbooks
- (7) Do not teach dogmatically.
- (8) Teach more about less. Limit the use of memorization.
- (9) Use scientific knowledge for social and individual purposes.
- (10) Better preparation of future teachers.
- (11) Develop habits of mind needed to become compassionate human beings.

If today's classroom teachers instituted some of the instructional methods suggested by reformers of late-nineteenth century science education, they would accomplish many of the recommendations reform movements address today. There would be many initiatives

remaining to incorporate, since late-twentieth century reformers envision a broader approach to science education reform than did the late-nineteenth century reformers.

Reformers today use many of the same terms, phrases, and jargon as those used in the late-nineteenth century. Some of them common to both eras are: relevance, experimental method, start with the known and concrete, avoid dogmatism, specimens in hand, use the real thing, teach more about less, show relationships between the various sciences, recognize no distinct boundaries between the sciences, begin with where the child is, use a spiral method of curricula arrangement, limit memorization, and teach the same course the same way for all students no matter what their destination may be.

One major phrase used in today's reforms was an often used phrase in the late 1800s. "Scientific habits of mind" was an aim of science instruction in the late-nineteenth century. Today it is a major component of reforms. Scientific habits of mind, in the late-nineteenth century, called for many of the same types of attitudes and skills expected of individuals acquainted with scientific ways of thinking and problem solving skills today.

Many of the reform ideas voiced in STS, Project 2061, and SS&C echo the cries from late-nineteenth century reformers (Tables 2 & 17, 19). Reform ideas in the late-nineteenth century arose in part due to the need to supplant the transmission mode of teaching, typical of late-nineteenth century classrooms, with a more active student-centered mode. The same agenda is underway today. Raizen (1991), director of the National Center for Improving Science Education, said that the roots of the current reform efforts in science education, in its attempts at activity-based education, together with the criticisms, go back nearly a century in the U.S. (p.9). Today, the concept of activity-based science instruction has changed much from the ideas of a century ago. Whereas the concept in late-nineteenth century high schools generally applied to the introduction of laboratory methods of instruction and the training of an individual's mental faculties, today

student-centered instruction is becoming more of a total involvement of students and groups of students, including students' involvement in curriculum and instructional choices in the science classroom.

The data presented in Tables 10 and 12 show that the lecture method still dominates the types of instructional methods used by teachers and that student experimentation is not very frequent. The transmission mode of instruction used by late-nineteenth century science teachers, is still a prevailing instructional mode in the majority of classrooms today. The ideas of reformers have not made it into most science classrooms.

If late-nineteenth century science educators called for the kinds of instructional processes in the first list above, then how can we explain the fact, that one hundred years later, the ideas associated with science instructional reform seem to have changed very little? There have been explanations for this.

Cuban (1984) suggested one of the most viable explanations for this -- survival. In order to survive in modern classrooms, or one in the late-nineteenth century with its myriad of students, calls for methods of instruction and classroom administration that make life easier and simpler for teachers. Classroom control, discipline, instruction, and assessment are easier for teachers if they transmit to students, knowledge to be learned and assessed. W.T. Harris (1891) said that restless Americans needed more discipline and the way he saw this being accomplished was to teach by memorization and recitation.

The simplest and easiest methods of instruction are to lecture and give students facts they are to *learn*. It may also be the easiest method by which to make assessments of student progress. With this type of instruction, there is a specific factual knowledge base that teachers expect students to know, and it becomes easy to test whether or not they know it. Numbers define student progress today, the same as they did in the late-nineteenth century.

One difficulty faced by reform movements under way today is student assessment. Looking for new and different ways to assess new and different ways of learning and **understanding** is part of reform movements. Dryer (1888) experienced problems with assigning grades and making assessments of students' work, for he recognized that studies in the sciences did not adapt themselves to the marking system currently in use. Dryer saw that the "[g]rowing powers of insight, constructive imagination, induction, generalization are not easily estimated in percentage" (p. 208). He recommended the use of practical problems for assessment of student work.

Perkinson (1984) offered another explanation for the "transmission" mode of teaching. He described this mode of teaching as a result of the influence of Bacon, experiential learning, and education as a means of social control (a view shared by Cuban (1984) as well). As a result of the Baconian idea that students learn by observing nature; sense perception and experiencing became important components of late-nineteenth century learning theories (such as Herbart's). Perkinson said that the idea of teachers as transmitters of knowledge resulted from them having had more experiences than the child, and thus had "...knowledge about how one should behave" (p.11). Therefore, teachers could transmit this knowledge or experience to students. "...[E]ducation had become a process of transmission through which the young could be disciplined, or trained, or socialized to the wishes of the adults responsible for them" (p.11). Perkinson described this as a "common sense" theory of knowledge, which is still a prevalent view today.

These facts make it clear that there are certain ways of teaching science that have been recognized as long as one hundred years ago to today that have yet to make it into the majority of classrooms. These ideas of science instruction have been suggested by two different eras of reform (but with a broader perspective today), and therefore must merit some special considerations in the reforming process. The descriptive terms reveal that

many of today's ideas about good science instruction are not new ideas to current reform efforts, but only revised and enlarged ideas.

3. A Top-Down Approach:

Science education reform efforts most often occur through national organizations, in a top down approach, from a panel of experts, and often are not implemented within classrooms.

The official science education reformation group in the late-nineteenth century was the Committee on Secondary School Studies (the Committee of Ten), sponsored by the NEA. A group of school men (one female) from colleges, universities, normal schools, and secondary schools made up this committee. Today, there is AAAS and its Project 2061, and the NSTA and its SS&C project, both with their advisory panels and numerous expert consultants. STS educational reformers are not affiliated with any particular national group, but their reform agenda takes place mainly through efforts of individuals or college teacher-educators associated with the movement.

Whereas the Committee of Ten assumed the enormous role of total curricula revision for all subjects in the high school, SS&C, STS, and Project 2061 share major concerns mostly limited to science (mathematics and technology) instruction. However, Project 2061 recognizes that systemic reform is necessary and that the total school environment, as well as teacher education, has to play a role in the reformation of science education. SS&C concerns itself more to the reformation of science curricula. STS tends to be a reform effort advocated by some leading science educators. Grants help finance the efforts of these reformers in disseminating their ideas and developing STS instructional

materials. Both SS&C and Project 2061 incorporate the STS model of teaching into their reform movements as one alternative method to science education.

The Committee of Ten was *the* reform movement of the late-nineteenth century. It took three days of collaboration, one hundred people, and a year to issue its final report. As far as restructuring the high school curriculum, late-nineteenth century educators had the Committee's models as the only guide. Today, there are numerous models and guides to assist science education reformers, and as each grows, others seem to bud off of these. They all intertwine in some basic educational principles and seem to overlap on many curricula ideas. These reform efforts are taking years of study and trials and are themselves in a continuous state of reform. Project 2061 and SS&C incorporate, and are in the process of structuring, many different teaching models and curriculum guides from which individual schools and systems can choose.

The report issued by the Committee of Ten was essentially its work. It was up to individual school systems to implement the recommendations. Professor Bryan (1895), of the University of Indiana, said that modern science was still outside the public schools and he recognized that it was not easy to get it inside, especially "between the lids of a handbook" (p.164). Evidently, in reference to the Committee of Ten, he said "You cannot get any of these things entirely and thoroughly inside from a committee of great outsiders who talk at the school" (p. 164). One criticism thrown at many reform efforts is that the reform is from the outside and is imposed upon schools and teachers.

"Teachers must be actively involved in the planning, acting, observing, and reflecting stages of reform research" (Shymansky & Kyle, 1992, p. 758). Teachers are the central agents in reform implementation, but the support role of administrators and the community is a vital part of reform implementation. Yet, most experiences with science

education reform show that they fail to make it into the majority of classrooms. Some factors that inhibit reform implementation in classrooms appear to be:

(1) A lack of communication between pedagogical experts and classroom teachers. This breakdown of communications can account for failure of reforms to impact on classrooms (Sarason, 1990; Shymansky & Kyle, 1992; Linn, 1992). The lack of communication could result in and from the isolation of teachers. The classroom situation of teachers tends to isolate them from participation in conferences and meetings where discussions of new ideas take place (Sarason, 1990; Linn, 1990). Yager (1992) noted that 85% of the middle and high school teachers are **not** members of the National Science Teachers Association, one of the main communicative branches geared towards science education. In the late-nineteenth century the lack of school systems, especially in non-urban areas, left many teachers isolated and totally dependent upon themselves. Today there are many educational associations and groups that can keep teachers up to date on current pedagogical ideas, but one first of all must become a member.

(2) Teacher emulation of the pedagogical approaches to teaching as exhibited to them by professional scientists. The use of the lecture method of teaching in college science classes may account for some part of the failure of reform efforts in the classroom (Yager & Penick, 1987). What is received in the transmission mode is taught by the same method.

Teacher education classes have limited involvement with prospective teachers compared to the time spent in the future teachers' major departments. In the case of late-nineteenth century teachers, normal schools trained future teachers in pedagogical methods, but often, such as with Herbartism, these methods, in practice, became *hollow formalism* (Meyer, 1957). Today the possibility of changing reform ideas at the classroom level into hollow formalism remains equally viable as that which occurred in the late-

nineteenth century when teachers are unprepared to implement reform processes that they know little about.

(3) Teachers sometimes resist change, not because they are stuck in their ways, but because they lack the knowledge to implement new ways and means of instruction, or because they hold basic beliefs about education that prevent change (Shymansky & Kyle, 1992). Rice (1893) made the same comment about teachers of his day. He said that it was not the lack of desire to do a better teaching job, but the lack of knowing how to teach that caused the poor state of education that he observed. New teaching skills associated with technology education and the use of new technologies in the classroom could place today's teachers in much the same situation as described by Rice.

Also, the added need to understand philosophies about the nature and history of science could put today's teachers in the position of lacking the know-how to incorporate reform visions of the late-twentieth century into their classrooms. Without support and training, the push for use of high tech equipment in the science classroom could leave many science teachers at a loss for knowing what to do with the equipment.

(4) Community and school values influence the practices of schools. Many communities may not welcome reform efforts (Cuban, 1990a; Shymansky & Kyle, 1992). Even in the late-nineteenth century, the perception of some communities as to the role of schools dampened the effects of reform and became a stumbling block to the institution of the *new* education (Coulter, 1893). Reform efforts today still must overcome the obstacles of tradition.

(5) Many reforms do not become policy or there is a lack of strong administrative initiative to support the implementation of new ideas (Anderson, 1992; Shymansky & Kyle, 1992). Some school systems eventually adopted the curricula designs of the Committee of Ten. The fact that the report of the Committee of Ten was widely read and

argued, and the fact that it supplied the only educational reform plan supported by a national organization, enhanced its chances of adoption by newly forming high schools. However, it was mainly the mechanical aspects of school reform that school systems adopted from the Committee of Ten report. Schools more easily accomplished the institution of curricula designs than the adoption of new ideas of instructional practices. The traditional role of the school easily accommodated new curricula designed to fit within that tradition, but the traditional school did not as easily assimilate new instructional ideas.

The most important thing for any reform effort is its implementation in the average classroom. If classroom implementation fails, then there just as well have been no reform movement. In order for classroom implementation to occur, teachers must believe in and institute reform initiatives. When it finally gets down to classroom instructional methods, reform becomes a personalized agenda. Reform movements must interest, utilize, and respect practitioners. They must be usable by teachers and supportive of teachers' efforts at reform. Without financial, moral and community support, teachers may feel isolated and unrewarded for their efforts. Lack of continued support makes it easy to slide back into old habits and give up attempting reform instructional methods.

Lack of support, traditional values and classroom survival seem to hamper instructional reform implementation. What schools have always been -- a place to learn (memorized) facts -- and the demanding situations teachers face daily, seem to enhance the prospects that instruction will continue to occur through memorization and drill based upon authoritative roles of textbooks and teachers.

4. The Laboratory Method:

Laboratory or hands-on science is a major instructional method recognized by science educators as the best method of instruction in both eras.

Science education reformers of the two eras in this study may have visualized different processes of hands-on instruction, but in both times educators recognize the importance of this method of instruction. The Baconian philosophy of experimental science influenced late-nineteenth century reformers and experimentation became the ideal method of instruction for science classrooms. Constructivism, as a new means of knowing, influences late-twentieth century reformers and hands-on experiences again become an ideal instructional method for science classrooms. In both cases, reformers call for actual experience with nature. There may be arguments about which branch of science should be taught first, such as chemistry before physics or physics before chemistry, but ideas about the *correct* means of instruction always include pupil experimentation with the real objects under study.

One main concern of the late-nineteenth century was that the lab method was non-existent in most science classes. The lack of qualified teachers and the costliness of providing lab experiences inhibited the use of laboratory instructional methods. As late-nineteenth century classroom teachers established laboratory instructional methods, they appeared to be adapted to the pre-established traditional curriculum (Tables 13 & 15). Laboratory experiments often were textbook exercises from which pupils received no added benefits than was usual in traditional classrooms (Martin, 1885), but the reformers of the late-nineteenth century were successful in one aspect of science education reform -- labs became recognized as a special and necessary part of science instruction.

Science represents a study of the phenomena of nature and thus the study of science involves the use of real nature and things. Both eras emphasized this one idea very strongly. Students must be able to dig in the dirt, watch seeds germinate, observe animals in their habitats, smell the flowers, test the waters, chart weather patterns, watch the moon and its phases, send balls rolling down an incline and measure speed, investigate the decay of Styrofoam and plastics in landfills, draw and record clearly and concisely, and learn how to approach problems and try out their own ideas about how to solve them. Late-nineteenth century literature overwhelmingly encouraged exposure of students to natural phenomena.

Today, hands-on methods of instruction are highly emphasized. Science is done by experiencing, a theme common in both eras. It appears that reform efforts in science education, whether calling for verification and affirmation laboratory exercises, or problem solving situations that call for student initiated ideas and designs, require that instruction occur through direct contact with phenomena and things.

5. Definitions of Science and Technology:

The definition of the nature of science, scientific knowledge, technology, and technological knowledge influence conceptions of how science is learned and instructional methods used.

Educators of the late-nineteenth century viewed science in positivistic terms. The Baconian views of experimenting and inductive reasoning supported instructional methods suggested at the time. The important position that laboratory methods held in reforming science instruction from its purely classical tradition of memorization and recitation, can be seen as an expression of the positivistic tradition.

Of course, the positivistic view of science was two hundred years old, so one may wonder why it took so long to become a means of science instruction in schools. Experimentation was always present for seventeenth century scientists, like Newton, Boyle, and Hooke, who accepted Bacon's experimental philosophy of science. Experimentation was a vital part of science.

Common people had little exposure to science and probably were more involved with everyday types of technology than with scientific processes. With the explosion of industrial processes in the nineteenth century and with the concern in the United States for social reform, education, and science education in particular, became a demand in common schools. The American faith in education, as a cure-all for social ills, combined with the new scientific and technological times resulted in a new faith in science.

Science became a necessary part of schooling in the late-nineteenth century in order to provide common people with a means of dealing with the technological society in which they lived. People could apply processes of scientific thinking to problems of society, and thus social ills would dissipate. In order that people acquire these skills in their own lives, science education became necessary and as shown earlier, the laboratory method of instruction became the means to instill and train students in the processes of science.

Today the view of science as socially constructed consensus knowledge is beginning to have an effect on science instructional ideals. This new view of science may have been around for fifty years in the science philosophers' world, but only recently has it entered into the area of science educational thought. It is this new view of science that appears to be structuring science education reform. Ideas of science instruction appear to mirror conceptions about the development of consensus-based scientific knowledge.

Today, constructivist teachers encourage the use of students' questions about phenomena they observe. They encourage discussions and different opinions. They see

students as constructors of their own knowledge based on their preconceived ideas, and they encourage the assessment of student progress, not in terms of numbers, but in terms of problem solving situations and applications.

The social construction of knowledge is one idea that today's science reformers adopt. Science educators see the construction of scientific knowledge by students as a process similar to that by which the construction of scientific knowledge has taken place. Social and experiential processes of learning are important in science education and in developing scientific knowledge bases. Processes of science become important in this educational view of the nature of science. Facts are seen as of secondary importance and emphases shift to hands-on approaches. Instructional methods proposed for today's science classrooms mirror the conceptions that scientific knowledge is constructed from real experiences of students.

As noted by Perkinson (1984) and Shymansky & Kyle (1992), empiricist philosophies still tend to guide many classrooms today. The idea of scientific knowledge waiting somewhere out in the world, ready to be discovered through the senses is still prevalent. The transmission mode of learning science still takes place as "knowledge" flows from the teacher to the student.

Instructional methods and learning theories involved in science education cannot and should not be static. Methods and theories of science instruction change with prevailing ideas of the nature of science. It therefore becomes important for science teachers to have a background in the history and philosophy of science and to understand and implement in their classrooms, activities that help establish relationships between the nature of science and science instruction. "The process of learning and teaching then, must reflect the dynamic, open-ended, aesthetic, and investigative dimensions of science" (Shymansky & Kyle, 1992, p. 753).

Science was the process and technology was the product in the view of late-nineteenth century society. There was no concern for teaching about social implications of technological effects on society, only about *scientific* discoveries and innovations. Innovations and industrial processes were the outcome of scientific knowledge. Technology, as a separate and equal partner in science classrooms, was non-existent in late-nineteenth century school science.

Today, with differing views of science and technology, knowledge about technological processes becomes an important concept in science education. Science education reformers today recognize the role of technological change and its effect on society and they recognize that science and technology reflect and shape cultural values (AAAS, 1989). Technology education becomes a partner in science education reforms of the late-twentieth century. In order to understand the world and problems of the late-twentieth century, students need a grasp of scientific and technological matters (Anderson, 1983). Today science teachers must be able to deal with technology instruction in addition to reform ideas about science instruction.

6. Craft vs. Research Knowledge:

Craft knowledge of teaching, in many instances, leads to some of the same teaching methods as that produced by late-twentieth century formal research.

Craft knowledge was the basis for teaching ideas suggested in the late-nineteenth century, for there was little or no research into processes of science teaching. Today, our reform movements express many of the same kinds of instructional ideas as those of the late-nineteenth century, but years of research into science instruction back up these ideas.

When late-nineteenth century educators examined science teaching, all they had to go on was a type of instinctive knowledge or knowledge based on what they saw good teachers doing. Their craft knowledge resulted in ideas about good science teaching. Charles Dryer (1888) wrote about some *aphorisms* of good science teaching. He did not know the origin of these sayings, but said they "...crystallized out of the general atmosphere of good teaching" and suggested that they serve as a guide in all science instruction. They are as follows:

Never teach indoors what can be learned out of doors.

Never explain in the abstract what can be demonstrated in the concrete.

Never teach with books what can be perceived in objects.

Never teach by image when nature herself is at hand.

Never show dead nature when living nature is attainable.

Never require belief where seeing and understanding are possible (p. 207).

Translated into today's reform efforts, these same sayings could be drawn from reform literature based on research in science teaching. Project 2061, STS, and SS&C express ideas that students need to have opportunities to: study real life, get acquainted with things around them, observe, collect, begin with the concrete before moving on to the abstract, learn through experience not through textbooks, and be involved with hands-on experiences. Many of these are reminiscent of Dryer's 1888 aphorisms.

Shulman (1987), as discussed earlier, identified four sources of the knowledge bases that teachers employ. One source of these was the "wisdom of practice." He defined this as ideas about teaching that come from practice in classrooms. Active participation by the teacher in learning processes results in knowledge about the processes. Perhaps the craft

knowledge that led to instructional ideas about science teaching in the late-nineteenth century is the "wisdom of practice" knowledge base of which Shulman spoke.

Today there is a large research base in science education from which to draw data to support the ideas of reform movements. Shymansky and Kyle (1992) pointed out that "...more often than not, published studies fail to impact on the communities of researchers, practitioners, teacher educators, or policy analysts/decision makers" (p. 756). They also point out that most research in science education has little relevance to the experiences of teachers and students and that "most science education research produces knowledge in the context of a system clinging to tradition" (p. 756). While formal research seems to make little change in classroom instruction, it appears that craft knowledge retains a position of importance in ideas about teaching methods.

II. Recommendations

What can be done to get science education reform ideas into the hands of practicing teachers and implemented in classrooms? Research shows that classroom teaching remains very much a personalized agenda (Tables 9-12). As the historical perspectives in chapters two and three show, reformers make their recommendations and suggestions about methods of good science teaching, but at the classroom level teachers often lack the know-how, the support, or the desire to implement such reforms.

Many times teachers do not realize that reforms are underway because information about reform efforts does not get to them. Often, information about reform movements and recommendations are published in professional journals to which teachers lack easy access, or in some cases, even knowledge of their existence. Although disseminating

information about reform movements to classroom teachers is a problem, it is an easier task to provide teachers with reform information and reformed curricula than it is to get teachers to implement the concepts and curricula of reform.

Late-twentieth century research data, shown in Tables 9-12 of chapter three, reveal several facts that are of use in deciding how to get reform ideas to classroom teachers. These facts are:

- (1) Teachers have a great deal of control about how they teach.
- (2) Teachers have a fair amount of freedom concerning their curriculum.
- (3) The majority of teachers use textbooks as the main informational source for their classrooms.
- (4) Research on pedagogical matters does not reach classroom teachers and is most often viewed as irrelevant to their situations.
- (5) Teachers often feel isolated in their work and lack support from other teachers, administrators and the community.

Based on these data, it appears that if reformers want to get reform initiatives into schools, then they must begin with those things that most often influence teachers' choices in instructional and curricula behavior. As listed above, the one thing that teachers use most often in the classroom to determine the curriculum and guide their instructional methods is the textbook. This seems the most logical place to begin to initiate reforms. *Science For All Americans* states, "Textbooks and other teaching material in current use are--to put it starkly--simply not up to the job; and the potential of computers and other modern technologies has yet to be realized" (p. 166).

It is through the combination of computer technologies and the revamping of the traditional concept of textbooks that the author recommends a means to bring science education reform efforts to classroom teachers. The reform efforts of the 1960s tried a revised textbook directed curriculum, and it met with limited success.* The author calls for a new kind of textbook instructional package that will inform, teach, and provide instructional materials for both teachers and students in the atmosphere of science education reform.

Of course, when the idea of reforming science education through the use of a textbook is suggested, science educators respond with a discouraging cry of *teacher-proof* curricula. Teacher-proof textbook reform initiatives provide teachers with all the necessary instructional materials and step-by-step procedures that supposedly lead to teaching by the book (as research shows most teachers do anyway). Teacher-proof textbooks leave no room for teachers to incorporate the intelligence and *wisdom of practice* they possess into the instructional program. The author is **not** calling for a new textbook that tells teachers what to do and when to do it, but rather calls for a new form of textbook, a technological textbook. The term textbook is not really appropriate for the type of manual, encyclopedia, or multimedia text envisioned by the author.

The technological development of the CD-ROM and multimedia computer methods open doors to science education curriculum designers and researchers as a means of providing teachers with materials and information relating to newer teaching ideas and methods. A science CD-ROM instructional package would include the following:

* This is the stance taken by modern day reformers. Of course, as this study has indicated, the ideals for reformers today are different than those who reformed science education three decades ago. Reformers today call for new and different ideals, and these new ideals call for different approaches to reform.

- (1) A scientific and technological encyclopedia. This section would include historical vignettes, cross-referenced to instructional topics.
- (2) A full year of *The Science Teacher* and *Children and Science* or other teacher oriented practical magazines which would like to be a part of this project.
- (3) A review of current of instructional methods, learning theories, and reform movements pertaining to science education.
- (4) Science text at three appropriate levels for adaptation by the classroom teacher for use in the classroom. This would most likely be organized by topics, themes, concept or interdisciplinary approaches to science education.
- (5) An easily usable, cross-referenced index which would direct teachers to related topics and different suggested instructional methods.
- (6) An activities section that would provide many different ideas and different instructional procedures for various activities. This section would also be cross-referenced to topics, themes, concepts, etc.
- (7) A section on the preparation of materials, chemicals, etc., along with safety precautions and waste disposal information.

A CD-ROM science curriculum package would incorporate and coordinate ideas from all three of today's reform movements. Organized around scientific topics, concepts, or themes, it would provide information and instructional material for different grade levels; primary, elementary, middle school and high school. It would provide individual teachers with different types of curricula from which choices could be made. Although designed for individual teacher use, teams of teachers within a school or school system could choose curricula designs based on STS courses, Project 2061 initiatives, the spiral curriculum of SS&C or national standards.

In addition to different curricula designs, other materials supplied in this instructional package would include background information on science or technology topics for teachers. Teachers could choose and print selected material to serve as the students' text supplemented by another informational CD-ROM especially for students. Teachers, schools, systems, etc., could choose from a variety of different curricula designs, even could mix and coordinate for their own personalized and different approaches to scientific and technological topics.

The problem with this program, of course, is much the same as that experienced by other reform efforts. Cost, support and the availability and actual use by classroom teachers. All teachers will not have access to CD-ROM technology, and many will lack the know-how, but these are some problems that reformers just cannot solve, but must deal with as best they can. The best reformers can hope to do for practicing teachers is to get new instructional processes to them. If as Robert Yager (1992) cited, 85% of the science teachers in the United States do not belong to the NSTA, a major means of sharing instructional ideas and theories, then somehow these teachers must receive information about what is going on in science education research. Teachers often see formal research studies as non-relevant to them, so a concentrated effort would have to be made to make sure that reviews of new instructional methods and ideas about learning were introduced in situations that teachers would find applicable to their classrooms.

This type of project would require numerous contributors and could not be a one time effort. A yearly update, on CD-ROM, would be provided. With a yearly update, the content and instructional ideas would be kept current, because as this study shows, changing times require constant science education reform.

As Project 2061 recognizes, a concerted and long term investment must be part of any reform effort. In any long term endeavor, however, reformers must also realize that

their suggested reforms will need reforming as new data and information about science teaching emerges from research and the reform movement itself.

Whereas the Committee of Ten, and other individual educators of the late-nineteenth century recommended change, it does not appear that they made as concerted an effort at reform implementation as is now occurring. The science conferences of the Committee of Ten met and decided the science curricula for high schools in a three day period. Reforms today are based upon research spanning the last couple of decades, and efforts that are to continue over a long period of time -- even until 2061. The process of reform is visualized today to be a major, long term endeavor that involves the entire traditional structure of schools. The vision of a CD-ROM multimedia, instructional and informational toolbox is one means of overcoming the traditional role and concept of the textbook in science classrooms.

Both eras identify exemplary schools and innovative teachers, ready to try new ideas and instructional methods. These teachers and schools show that reform ideas can make it into classrooms where teachers are encouraged and supported in their efforts to try something new. With newer, faster and more global means of communications, hopes of reforming late-twentieth century science education appear to have a better chance of implementation as information about science education reform becomes more assessable to larger numbers of classroom teachers.

Today we have seen reform movements come and go. They often provide needed equipment and supplies necessary to conduct a reformed classroom and reform efforts have made in-roads into establishing more humane instruction methods. Perhaps, most importantly of all, reform efforts provide reasons for, and means of, critically looking at and discussing current states of science education. Dialogue and discussion are important aspects of building knowledge, whether it is knowledge about science and technology or

science or technology education reforms. There is a necessary place in science education for reform, for in all of the discussions, debates, trials, and conflicts, there is hope for better science instruction for all students.

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