Order Number 9416766

The Conceptual Change Strategy of Teaching in the teaching of high school chemistry

Stricklin, Rebecca Ellen, Ed.D.

University of Cincinnati, 1993

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

UC

THE CONCEPTUAL CHANGE STRATEGY OF TEACHING IN THE TEACHING OF HIGH SCHOOL CHEMISTRY

A dissertation submitted to the

Division of Research and Advanced Studies
of the University of Cincinnati

In partial fulfillment of the
requirements for the degree of

DOCTOR OF EDUCATION

In the Department of Curriculum and Instruction
of the College of Education

1993

By

Rebecca Ellen Stricklin

B.S., Ohio University

M.S., Ohio University

UNIVERSITY OF CINCINNATI

December 7, 1993

I, Rebecca Ellen Stricklin,
hereby submit this as part of the requirements for the degree of:

Doctor of Education

in Curriculum and Instruction

It is entitled The Conceptual Change Strategy of Teaching in the Teaching of High School Chemistry.

Approved by:

Thaddeus W Fowler

Glenn C. Markle

Barry D Smith

John J Alexander

ABSTRACT

Students come to chemistry class with certain ideas, expectations, and concepts already in place. Learning may occur in the intersection of this preconceived state and what is being taught. If teachers can predict when this learning may occur and if teachers can predict under what situations the likelihood of increasing this intersection may be improved, learning may be increased and facilitated.

One apparently effective approach to facilitating learning is the use of The Conceptual Change Strategy of Teaching. In The Conceptual Change Strategy of Teaching, the student becomes the focus in the classroom forming and defending hypotheses; explaining the thought process behind the formation of the hypotheses; and then testing the newly formed concepts in new situations. The teacher's role becomes a facilitator of the process providing a free and open forum and also in providing events such as demonstrations, laboratory work, or other discrepant events to help the students' learning process.

In this study, a working definition of The Conceptual Change Strategy of Teaching was developed. Using this, a self-reporting, valid and reliable survey instrument was developed that measured whether or not a high school chemistry teacher was using The Conceptual Change Strategy of Teaching in the classroom. Finally, this instrument was used to see if the high school chemistry teachers in the greater Cincinnati area have a Conceptual Change Strategy of Teaching orientation.

TABLE OF CONTENTS

V. CONCLUSIONS

LIST OF TABLES

TABLE Page

LIST OF FIGURES

FIGURE Page

CHAPTER I

INTRODUCTION

AN INTRODUCTION TO CONCEPTUAL CHANGE AS A NEEDED TEACHING STRATEGY

Students come to chemistry class with certain ideas, expectations, and concepts already in place. Learning may occur in the intersection of this preconceived state and what is being taught. If teachers can predict when this learning may occur and if teachers can predict under what situations the likelihood of increasing this intersection may be improved, then learning may be increased and facilitated.

One apparently effective approach to facilitating learning is the use of The Conceptual Change Strategy of Teaching. In The Conceptual Change Strategy of Teaching, the student becomes the focus in the classroom forming and defending hypotheses; explaining the thought process behind the formation of the hypotheses; and then testing the newly formed concepts in new situations. The teacher's role becomes a facilitator of the process providing a free and open forum and also in providing events such as demonstrations, laboratory work, or other discrepant events to help the students' learning process.

The Conceptual Change Strategy of Teaching is a strategy in which students' conceptions in science are challenged. There is an event which causes students to want to change their previous conceptions. Students must verbalize what their concepts were, what they are, and their thought process in changing them. This learning sequence is based on the conceptual change theory of Posner et. al. (1982).

Students acquire and store information in two main ways. One is memorizing facts presented. If the teacher sticks closely to the book and evaluates using standardized objective tests based on recall of the text, this often suffices a student in achieving high scores on these evaluations. However, since there is no application of the knowledge or use of it at a higher level of cognition, the short term memory or vague coding quickly fades and no learning has occurred. The second way of acquiring and storing information is to incorporate it into one's consciousness. The later method means the concepts can be used in application situations and are more likely to be retained. If this occurs, meaningful learning has occurred because the student retains the concepts and be able to use them in new situations.

Few people are willing to alter their current understandings unless there is strong evidence to do so. It is more likely that the person will check to see if new concepts fit with one's current beliefs and ideas, with other knowledge or with past experience. If the new concepts do not fit, they are ignored. With students it is even more difficult to alter current beliefs because they have only vague, current frameworks with which to compare new concepts. So, they ignore new concepts as irrelevant because they have no place to fit these within their preexisting frameworks (Driver and Easley, 1978). If teachers can recognize this, they can prepare to build a more substantial framework or better relate to whatever vague framework that exists.

Concrete evidence and examples need to be presented for students to see anomalies. A real sense of disequilibrium needs to be created so that students are willing to try to resolve the discomfort created by the disequilibrium

(Hewson and Hewson, 1982). This discomfort is a key to creating the situation most likely to promote accommodation.

This perspective of the student in The Conceptual Change Strategy of Teaching then means several things for the teacher. The teacher changes from an information giver to two different major roles. One role is preparing exposing events that actually challenge the learner's preconception and later providing novel situations in which to test the new conceptions. This role is critical because the exposing event must be challenging enough to create excitement in the learner and the closing situation must be one that is new and unique and tests only the correct new conception. The other major role, which is unique to The Conceptual Change Strategy of Teaching, is the role of providing an environment that encourages and promotes critical thinking and one in which the thought process is as important as the "final answer".

THE RATIONALE

Some high school chemistry teachers exhibit special characteristics. These high school chemistry teachers are more involved with their students and their students do better in some tangible ways; they are more involved in professional organizations; they make presentations that are involving and interesting; and they are generally recognized whenever you think about chemical education. Are there identifiable differences between these high school chemistry teachers and other high school chemistry teachers? Are these differences based on different methodology? different beliefs? different training?

For this study, a more objective focus was chosen - studying a teaching strategy. A teaching strategy different from lecture, recitation, or assessment was chosen. There were two reasons for this choice. First, lecture, recitation, and assessment have been researched frequently. Secondly, those strategies are standard and traditional and a unique approach was sought.

In chemistry, inquiry strategies with visual or concrete examples are important. The first strategy considered was the use of the laboratory. Although this is widely studied in chemical literature, educational literature has ruled it out as a viable cognitive strategy since no study has shown the use of the laboratory to increase cognitive ability. The second strategy considered was the use of discrepant events. Discrepant events are used as an activity and are loosely tied back to theory but are not theory-based. This led then to The Conceptual Change Strategy of Teaching which is theory-based.

The Conceptual Change Strategy of Teaching was found to be an exciting strategy that brought together many of the other ideas considered. The Conceptual Change Strategy of Teaching is a new strategy that is at the intersection of many theories - inquiry, The Learning Cycle, and The Constructivist Theory. The Conceptual Change Strategy of Teaching involves the use of visual or concrete examples, seems to cause true learning and not just memorization, and uses transferable skills so the learning is more valuable in the long run.

Although The Conceptual Change Strategy of Teaching is at the intersection of several much older strategies, the theory behind the strategy was not developed until 1978. Several different research teams worked on the theory and a major conference was held at Cornell University which included a segment on conceptual change theory. Most of the research in this area between 1978 and 1988 was around defining the terms of conceptual change and how it fit with existing theory and epistemological studies.

Research studies in the late 1980's and early 1990's have looked at the extension of the theory into the area of conceptual change. Conceptual change was viewed mainly from a theoretical standpoint and a definitional aspect of learning rather than from a theory of instruction. A further extension of the learning theory into practical application in the classroom was sought. No published definition was found of this strategy of teaching or research published on this instructional aspect.

There were a number of reasons for performing this study. One of the most important reasons for performing the study was to develop a definition of The Conceptual Change Strategy of Teaching. This was accomplished by tying together the recent literature studies on conceptual change theory, the conceptual change strategy theory, and extracting the application of the conceptual change strategy to instruction as The Conceptual Change Strategy of Teaching.

Second, it was important to perform the study to develop a checklist of The Conceptual Change Strategy of Teaching that can be used in assessing the use of The Conceptual Change Strategy of Teaching in the classroom.

Third, it was important to perform the study to see how much The Conceptual Change Strategy of Teaching is being used by high school chemistry teachers in the four counties of Southwestern Ohio.

This study will benefit several different groups. One of the groups that this research will benefit are educational researchers by setting the three benchmarks of: (1) setting a definition of The Conceptual Change Strategy of Teaching; (2) making a checklist of the phases of The Conceptual Change

Strategy of Teaching as used in the chemistry classroom; and (3) determining to what degree The Conceptual Change Strategy of Teaching is being used by high school chemistry teachers in the four counties of Southwestern Ohio. A workable definition that can be referred to is always helpful as a general point of departure. The checklist is important in that it can be used by researchers in other areas of the country, in other subject areas, or in other classrooms. The development of an instrument to measure the use of The Conceptual Change Strategy of Teaching may be useful to other researchers who want to study this area.

The Conceptual Change Strategy of Teaching is a new strategy that is at the intersection of many theories - inquiry, The Learning Cycle, and The Constructivist Theory, uses many of the techniques of these other strategies, and The Conceptual Change Strategy of Teaching is a viable method. The Conceptual Change Strategy of Teaching involves the use of visual or concrete examples. Early studies have shown that it is a viable method.

Since The Conceptual Change Strategy of Teaching appears to be a viable teaching strategy, faculty of departments of chemistry may want to consider offering workshops that teach how to develop and/or use the visual and concrete examples needed for The Conceptual Change Strategy of Teaching. Since most major chemistry workshops already have been developed to teach demonstration and lab skills and integration, only a new emphasis may be needed ; an added emphasis on the integration of the technique of The Conceptual Change Strategy of Teaching. More teachers will feel the need to incorporate the visual and concrete examples and the use of The Conceptual Change Strategy of Teaching as more key teachers whom they admire and try to emulate use these techniques in their classrooms and in presentations. Faculty of colleges of education need to know more about The Conceptual Change Strategy of Teaching so they can teach this method of instruction.

The Conceptual Change Strategy of Teaching fits with other strategies of teaching.

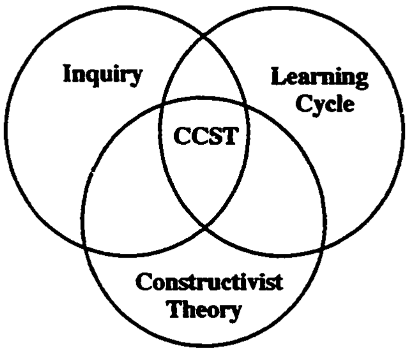

Figure 1. Strategies of Teaching.

The Conceptual Change Strategy of Teaching is an inquiry strategy but all inquiry is not The Conceptual Change Strategy of Teaching because all inquiry does not use the sequence needed for The Conceptual Change Strategy of Teaching.

Some of the steps of The Conceptual Change Strategy of Teaching are the same as those in the Suchman Model. In the Suchman Model, the steps are: encounter the problem; inquiry through questioning, the collection and analysis of data, and the generation of hypotheses; and analysis of the inquiry strategy with an emphasis on the development of more effective strategies (Joyce and Weil, 1972). These step are also necessary and present in The Conceptual Change Strategy of Teaching. The different steps necessary in The Conceptual Change Strategy of Teaching are: a step when the learner is "discussing" (orally or in writing) the thought process as the learner is going through it, and a step when the new hypothesis or strategy is tested in a new situation.

The Conceptual Change Strategy of Teaching also has some of the same steps as in The Learning Cycle and in The Constructivist Model. However, all examples of The Learning Cycle and The Constructivist Model do not fit within The Conceptual Change Strategy of Teaching since The Learning Cycle and The Constructivist Model do not require models nor the first and last steps of The Conceptual Change Strategy of Teaching.

The Conceptual Change Strategy of Teaching appears to cause students to learn. The Conceptual Change Strategy of Teaching would seem to cause true learning due to students having to verbalize their thought processes and not just memorize facts. The Conceptual Change Strategy of Teaching uses transferable skills in the application process so the learning is valuable in the long run. Ultimately, it would be good to know if The Conceptual Change Strategy of Teaching is a better method of students learning. This study lays the foundation for follow-up studies which will address these important issues.

STATEMENT OF THE PURPOSES

This is a descriptive study in that it looks at "what is going on out there." The study specifically determines the percentage of responding high school chemistry teachers in the sample who use The Conceptual Change Strategy of Teaching in their classrooms.

The four purposes of this study are:

1.) to define The Conceptual Change Strategy of Teaching and to develop a checklist for use of The Conceptual Change Strategy of Teaching in the classroom and to achieve agreement with Conceptual Change Strategy experts;

2.) to develop a self-reporting, valid and reliable survey instrument to assess the use of The Conceptual Change Strategy of Teaching from a distance;

3.) to survey the high school chemistry teachers in the sample and have the majority of the instruments returned; and

4.) to gain some insight into why teachers use or do not use The Conceptual Change Strategy of Teaching so that a more definitive follow-up study could be performed in this area.

LIMITATIONS

This investigation was conducted to develop a definition of The Conceptual Change Strategy of Teaching, develop a checklist of its use, and then see if this strategy was being used in southwestern Ohio. Since the study started at this point, it may be used as the benchmark from which other studies may follow. An attempt was made to establish who is using the The Conceptual Change Strategy of Teaching. Another study will be necessary to determine fully the explanations as to why some high school chemistry teachers are using The Conceptual Change Strategy of Teaching and some are not. It remains to be seen if there are identifiable and predictable characteristics of those high school chemistry teachers who are using The Conceptual Change Strategy of Teaching.

Literature reviews and early studies have shown The Conceptual Change Strategy of Teaching is being accepted as a viable method to use in the classroom. Later studies may attempt to see if The Conceptual Change Strategy of Teaching is a better method of instruction or just another alternative.

The scope of the survey was the southwestern Ohio area. Other studies may survey larger and more broadly based populations.

RESEARCH QUESTIONS

1. Is it possible to devise a definition of The Conceptual Change Strategy of Teaching?
2. Is it possible to transform the definition of The Conceptual Change Strategy of Teaching into a valid and reliable survey instrument?
3. Are there high school chemistry teachers in southwestern Ohio using The Conceptual Change Strategy of Teaching?
4. Is there enough information at this point to gain some insights into why certain teachers use The Conceptual Change Strategy of Teaching?

SUMMARY

While different authors define the Conceptual Change Strategy of learning differently, it is generally accepted that the Conceptual Change Strategy must include: providing an exposing event to challenge the student's current conceptions; having students form hypotheses about what they have seen; and asking students to describe their thought processes. A Conceptual Change Strategy of Teaching has not been defined previously and clearly.

The Conceptual Change Strategy of learning implies that The Conceptual Change Strategy of Teaching would have to proceed through the following steps. A teacher must assess conceptions before instruction, provide examples to challenge the conceptual framework, must provide examples which link the framework to the "real world", and, most importantly, allow time for concept assimilation by allowing time for students to articulate their understanding.

In this study, a working definition of The Conceptual Change Strategy of Teaching is developed. Using this definition, an instrument was developed that could measure whether or not a high school chemistry teacher uses The Conceptual Change Strategy of Teaching in the classroom. Finally, this instrument was used to see if the high school chemistry teachers in the greater Cincinnati area have a Conceptual Change Strategy of Teaching orientation in their teaching.

CHAPTER II

LITERATURE REVIEW

The review of literature is organized into eight categories: an introduction looking at science education today; an historical perspective on the teaching of chemistry; curriculum; instructional methodology and strategy; the theory of conceptual change; teaching behaviors; conceptual change strategies; and a summary of the review.

INTRODUCTION

The National Science Teachers Association (NSTA, 1971) stated the major goal of science education as being "to develop scientifically literate and personally concerned individuals with a competence for rational thought and action." The more general objectives are:

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

These objectives lead to the definition of a scientifically literate person as one who "knows how to use science concepts, process skills, and values in making everyday decisions as he interacts with people and his environment" (NSTA, 1971). Under these conditions and goals, the student becomes the focal point in needing to know the dependence of scientific knowledge upon the inquiry process and can distinguish between scientific evidence, theory, and personal opinion (NSTA, 1971).

The teacher's role, therefore, changes from one of disseminating information to enabling students to master skills and approaches to problems that can be used throughout the student's life. Objectives and lesson plans must be geared toward what they students need to achieve this goal of independent and unbiased thinking.

Development of the "new curricula" of the 1960's was an attempt to fulfill the goal of teaching thinking and processing skills. One of the functional descriptions of inquiry learning from the "new curricula" was by the BSCS Committee (Mid-continent Regional Educational Laboratory, 1969). Inquiry is a set of activities directed toward solving a number of related problems in which the student has as his principle focus a productive enterprise leading to increased understanding and application. The "new curricula" were designed so that the solution to the problem was not the end of the learning experience and that a solution did not always need to be found for learning to occur. The five characteristics which must be present for effective inquiry teaching are:

1. guiding principles;
2. inquiry factors;
3. behavioral objectives;
4. affective qualities;
5. inquiry-into-inquiry.

All objectives must be specific, measurable behavior performed under specified conditions and at acceptable levels of execution (Mid-continent Regional Educational Laboratory, 1969).

Science curricula have changed from traditional to the "new curricula" back to traditional, paralleling shifts in science curricula content and in methodology. Although our fast-paced technological society is boasted to be the best in the world, all citizens have not been able to keep up and some have been labeled as scientifically illiterate. The problem of teaching science has become a double-edged task of educating the best scientists to keep our place in the world scientifically and of educating all students to become scientifically literate.

Several noted educators have expounded upon NSTA's definition and position on scientifically literate students (Butts, 1986; Hurd, 1984, Showwalter, 1984) One of the most concise ways of defining the different aspects of scientific literacy has been proposed by Victor Showwalter, Capitol University (Showwalter, 1984) He has listed seven main areas to be included:

1. Nature of Science
2. Content
3. Processes
4. Values
5. Science-Society
6. Interest
7. Skills.

His areas are very similar to Butts' six and Hurd's eight areas. It is good to delineate the areas so that each is given attention; but in other ways the areas do overlap. This is a problem in not only defining and studying the areas but also in applying the research knowledge into practice.

1. The Nature of Science: In the last decade, the whole idea of the nature of science has been reexamined to see what it really does and should include. Penick (1978) has been studying the creativity and curiosity aspects of science and how these can be incorporated into the curriculum. He feels that

these aspects are fundamental to science and its study not only from a theoretical standpoint but also as a motivator for science. This follows some of the work of Shymansky (1985, 1987) and many others who have studied the elementary education process and how the curiosity and creativity aspects are what children are naturally inclined toward until stunted in their quests. Therefore, including these aspects of curiosity and creativity should be paramount not only in the curriculum but also in the instruction.

Bybee (1981) has worked on the implications of technology's effects on science and science education and how that has changed the nature of science in many people's minds. There has been a shift to emphasize so much of the technical aspect that the true nature of science is often overlooked or at least deleted from various curricula. With the advancement of microcomputers and other such technological ideas, Bybee and those who have been studying the role of computers (Herron, 1986; Groves 1985) fear that science may be moved into even more of a backseat role. Therefore, care must be given that science is included.

Yager (1984, 1985) has repeatedly stressed the need to define the nature of science being taught. Especially in Project Synthesis (Yager, 1983), Yager has defined the various aspects he sees that should be kept from the "new curricula" and what new aspects must be added. Hurd (1984) advocates the role of science and of scientists in developing new curricula. He advocates curriculum innovation and not curriculum revision to reflect the changes in science.

2. Content: The field is very fragmented when the issue of content is raised. There are the specific subject matter experts and their opinions, general scientists and their opinions, and educators and their opinions. The opinions

are based on research in some cases, on meta-analyses in others, on experience, and sometimes on just opinion.

From the chemists' viewpoint, Herron (1986) and Bodner (1985, 1990) have approached the question of content and what content should be included as well as the processes by which these are learned. Ramette (1985) has approached the question of content by saying that only theories that can be illustrated should be presented. The illustration can be by practical example, by lab, or by demonstration but it must be clear to the student or it should not be included. Bent (1985, 1986) has approached the question from the standpoint of the non-major or non-college-bound and feels that topics that are a hindrance and negative motivator should be eliminated from the curricula. He also advocates descriptive chemistry over theoretical chemistry because of the applicability and wants to dispel the myth that theoretical chemistry is the core and that descriptive chemistry is watered down for the ignorant.

From the educators' viewpoint, Ben-Zvi and Hofstein (1985,1986) have both studied the content and achievement levels and how concepts are mastered and advocate more practical examples and less of the theoretical base. Shymansky (1984) has studied the "new curricula" and has abstracted the content that he feels should have been salvaged when the rest was discarded. Gabel (1986) has approached the content area from the standpoint of what can be used in problem-solving examples.

3. Processes: The questions over processes have been debated for quite some time and and have especially dealt with the issue of which is more critical, the processes or the content. The opposing sides have been represented by Bruner (1961) and Gagne (Clarizo, 1974), with Bruner advocating more of a discovery process and Gagne advocating the guided approach. Shulman

(1968) advocated a middle-of-the-road approach of guided discovery and that has been used most recently.

From these, other people have proposed other ideas that have mainly influenced methodology whether it be the Taba inductive model, Ausubel's idea of advanced organizers, or Suchman's Inquiry method. The problem facing the scientific literacy experts trying to devise new curricula is to incorporate all these ideas and use different models to teach different topics depending on the students, courses, and classes involved. Hurd (1984) has proposed that processes are so important that the back-to-basics movement should be relabeled the 4-R's with the fourth being reasoning and that this may be the most important thing that can be taught in any course. Perhaps of fundamental importance is the process skills test being developed by Okey (1983) which, if found valid and reliable, could be incorporated into all courses in some facet.

4. Values: One of the few researchers in this field is Quinn and his studies with how attitudes affect values and vice-versa. Yet some of his work has been questioned in the Munby study (Munby, 1983).

5. Science - Society: One of the main proponents of the science-society connection has been Hurd (1984) and his steps in how to make more literate citizens. He advocates topics such as environmental concerns, nuclear energy, safety concerns, and acid rain. Yager (1985) has also been a great proponent and has suggested several ways of incorporating Hurd's ideas into practice such as the use of field trips, field studies, museums and nature centers, projects, and other such activities. The main point is that relevance and purpose must be maintained for the student's sake as well as for society as a whole both now and in the future.

6. Interest: Interest or attitudes is perhaps one of the most necessary and yet overlooked aspects of any educational study. Yet this trend of leaving out attitudes was changed with the major review of science education done by Renner (1976) and in all subsequent yearly reviews. Major work was contributed by Moore and Sutman (1983), Tamir (1984), Simpson (1978) and Shrigley (1979). However, the review of thirty major studies by Hugh Munby (1983) sheds doubt on many previous studies. Munby says the idea of attitudes is even more complex than first realized and that often "attitude" was not clearly defined enough for the studies to be valid. He defined attitudes in a hierarchal structure that had over a dozen different meanings depending on specific usages. He does use parts of the other studies. The main contribution, though, is to leave tracks of how future methodology might proceed and a list of criteria for future work and reviews.

From these studies and from the work of Yager and Hurd, it is evident that interest must be maintained so that students will not avoid science courses, will apply themselves once in science courses, will consider scientific careers, and will continue their interest in science by pursuing it on their own in the future.

7. Skills: Skills as an area of concern was first defined by Bates (1978) in his study of the lab and its processes. These ideas were corroborated by Yager (1984) and Blosser (1981); the lab is the best way for teaching the skills in use of equipment. Of newer concern, is the use of the microcomputer and the role it is to play in the classroom.

There are ways that science needs to be taught so that students are not just memorizing facts for a test. Use of The Conceptual Change Strategy of Teaching may fit this bill.

AN HISTORICAL PERSPECTIVE ON THE TEACHING OF CHEMISTRY

Too often students view chemistry either as a mystical, magical series of transformations or as an ideological thought pattern for intellectuals only. This leads to attitudinal problems that must be overcome. A similar view by educators has led to much of the pendulum-like movements in educational thought and research.

Chemistry has been used in some form almost since the dawn of time. The Copper, Bronze, and Iron Ages were based on the chemistry of the metals involved. In the Trial and Error Period, man expanded his use of science into making items for everyday use including: tanning chemicals, wine and beer fermenting, glass making, and drugs. However, the use of magic came into play and haunted science for centuries. During the Greek Age, the Golden Age of Reasoning, the use of thought process to study science began. Led by Aristotle, this process became the methodology. This process was basically lost from scientific studies for centuries afterwards and in some ways has still not been reapplied. This shows that the foundation for using The Conceptual Change Strategy of Teaching started centuries ago.

Scientific efforts continued in the Alexandrian and Roman Eras but almost disappeared from Europe during the Dark Ages. However, science had continued in the Arabic culture and formed part of the basis of the later renaissance of science in Europe; but cultural barriers, mainly in interpreting ancient Sanskrit and Arabic, both then and now have prevented the sharing of all of the information.

Scientific endeavors continued in China during the European Dark Ages, especially in the area of combustion with firecrackers, rockets, and gunpowder, but this would not be known in the Western world until the time of Marco Polo. The Chinese culture was based mainly on the philosophies of Confucius and much of this was directed toward the thought process again pointing toward The Conceptual Change Strategy of Teaching.

The Middle Ages in Europe were a reversion back to the Trial and Error Period and its mystical viewpoint with the development of alchemy. Galileo led the movement to experimentation. In the Twentieth Century, advancing technology has led to many discoveries. One example, in chemistry, was the discovery of Noble Gas compounds in 1963 marking another "new age" of chemistry. It is important to note repetitive trends in chemistry and to note how new modern chemistry is as a science.

The history of the American educational process is also important. There was little science in the early years of the Latin Grammar School (1635-1751). In the years of the Academy (1751-1821), there was the beginning of organized instruction in science including chemistry; but the curriculum was still dominated by the church. Group instruction was entirely by lecture and memorization of what was known at this time. Thought processes were not present and little advancement was made. In the Early High School Era (1821-1870), there was expansion of the science curriculum into other areas, but there was not much change in chemistry. Group instruction was still mainly lecture and only some discussion. At the college level, chemistry was mainly taught by the tutorial method.

The College Domination of the High School (1870-1910) was established when Charles Elliot, newly appointed president of Harvard, made science a requirement for admission. Standards for chemistry were developed by Josiah Cooke in 1886 including 83 experiments, 60 of which had to be completed and reported by high school students. Science curricula changed to meet these influences. Chemistry was the second most stressed science after physics. Laboratory instruction became popular, first in chemistry. In some schools, laboratory instruction was the only instruction used, especially in trying to meet Cooke's standards.

In the Period of Reorganization (1910-1930), high schools became resentful of college dictates. In 1920, the NEA Report of The Commission on Reorganization of Secondary Education was published listing recommendation similar to those published in 1982. There were few changes in chemistry except that laboratory instruction emphasis was decreased. In the following era (Critical Appraisals and Increasing Functionalization 1930-1945), courses of study were instituted, but there were few changes in chemistry.

During the Post World War II era (1945-1955), a greater emphasis was placed on the functional aspects of all courses, including chemistry. Lab manuals were rewritten and lost some of their cookbook style. Studies were made on facilities. Government money was poured into schools. Another national report was published. All these findings, again, sounded very similar to those of 1982 (Campbell et. al., 1980).

Beginning of Change (1955-1965) began with little change but this changed dramatically after the U.S.S.R. launched Sputnik in 1957. The Public demanded action. There was a shift back to intellectual disciplines and emphasis on processes. National Science Foundation funds were at their highest. Two new chemistry curricula were developed : The Chemical Bond Approach and CHEM Study; the latter is especially known for its laboratory approach.

In the Viet Nam and Post Viet Nam Period (1965-1980), there was a great de-emphasis on science. Few funds were available. Few new curricula were developed (Fowler, 1984).

It is hard to analyze the present era (1980 -) because we are in it and do not have perspective to look back. Many of the characteristics of the past are "recycling." College domination and laboratory emphasis is resurfacing from 1910 (Fowler, 1984). The 1982 report by the National Science Board (Educating Americans for the Twenty-first Century) is similar to several from the past. Emphasis on functional aspects are resurfacing from Post World War II. Facilities are being studied and some government money is being spent. The U.S. again feels behind, this time behind Japan and Germany. Studies are being made to reevaluate the "alphabet courses" such as CHEM Study and BSCS.

Again, certain significant things stand out. The repeating cycle stands out graphically with many lessons to be learned from the previous periods. Instructional response needs to find a happy medium instead of the far swings of the pendulum.

What then should be included so as not to get the "patchwork quilt" syndrome common of too many courses (Yager, 1984). Hurd (1984) has criticized science content as being bits and pieces of knowledge without unity. When laboratory work is used, the connection between it and the classroom content was often incidental and the laboratory work stressed developing manipulative skills rather than any type of problem solving skills. Most teachers "tell" science and worry about "covering the textbook" more than anything else. Hurd (1984, 1993) summarized this by saying:

1. high school science courses do not reflect science as science is known by scientists either in content or method; and
2. learning is insufficient and students are unable to make intellectual use of what they learn.

This would seem to indicate that a different strategy is needed and The Conceptual Change Strategy of Teaching might be one method of addressing these concerns.

There seems to be a swinging pendulum in the emphasis of science education that swings between major scientific emphasis and major affective emphasis. The Sputnik scare frightened people into spending lots of money on science and education and basics were tossed out. Then the science emphasis was tossed out as people reacted in the seventies and wanted more of "doing your own thing." Now the pendulum is swinging again and seems to be swinging too far to the back to basics movement (Fowler, 1984) The place of science needs to be included in the study of science education. As Hurd (1984) put it, reasoning should be added as the fourth R. Again, The Conceptual Change Strategy of Teaching may be a way of adding this reasoning component because students must think through their concepts and must be able to express their thought processes.

The synthesis reports are more informative than most individual articles in showing how historically different methodologies have interacted. The publication, Research within Reach, gives several generalized statements about methodologies employed including:

1. 78% of teachers are not qualified for inquiry;
2. most classrooms are very teacher oriented (often 90-99%);
3. studies reveal that the teacher is central to science education;
4. classes that are more student-centered are usually taught by teachers who have attended NSF courses (Holdszkom and Lutz, 1984).

The main types of outcomes that the ERIC editors have sought are:

1. skills
2. concepts
3. cognitive abilities
4. understanding the nature of science
5. attitudes.

The major problems outlined are the lack of consideration of teacher behaviors, classroom learning environment, materials, and other resources involved in the teaching-learning situation. The review continues with "The 13" criticisms of science education research from the Curtis Digests (Blosser, 1981) showing that often methodology problems led to the inability to reach conclusions.

Boyd, Dunn, and Kennedy published an article based on a seven-year study of 250 reports (Blosser, 1981). Much work was done in the 1930's and again in the 1960's but not as concentrated an effort has been done in other decades. Other conclusions include the fact that critical thinking needs to be stressed at all levels. Also is the fact that almost nothing is written on teacher behaviors in labs, the area is wide open, and that any and all research is needed (Blosser, 1981).

Lunetta and Tamir concluded that teachers should move to methods and strategies that emphasize hypothesizing and predicting consistent with the work of scientists and the understanding of scientific relationships, concepts, and models (Holdszkom and Lutz, 1984). Again, this is a foundation for The Conceptual Change Strategy of Teaching.

The role of the teacher, the teacher behaviors, and what choices the teacher makes are paramount to the learning experience. A new wave of research in the 1990's is focusing on these issues.

CHEMISTRY CURRICULA

Until the mid 1980's, the curriculum most often used in high school chemistry courses was the Modern Chemistry series (Yager, 1984). The textbook offered content in both the theoretical and descriptive modes. Most of the material was straightforward and the exercises at the ends of chapters were basically "rote" problems. The majority of the experiments in all versions of the accompanying lab manuals were along the lines of Shulman's middle-of-the-road theory but leaned more toward "the cookbook style." There were questions in the procedures and at the end of the experiments that called for conclusions but these tended to be factual and conceptual and not process-oriented. Process skills had to be enforced by the teacher as the curriculum did not require them. So if process skills were included, the teacher became the focal point.

Since then, the market has been shifting as other curricula have focused upon various issues with the Prentice-Hall series promotion of problem solving skills, the Heath book promotions of being "like Chem Study", and the ACS ChemCom promotions of being the new curriculum for the nineties.

Criticism regarding the traditional approach has focused on the methodology of the teacher stressing facts and information only without conceptual unity. Often, content was out-of-date. Most teachers used the method of telling and the overlying main goal was to "finish the textbook." Lab work was to teach processing skills; but connection between the classroom and lab were incidental. The lab work that was done was done to teach physical skills and not problems in systematic thinking (Hurd, 1970).

To meet the criticisms and the public outcry after Sputnik, the "new curricula" or "alphabet courses" were developed. Chemical Education Material Study (CHEM Study) was begun in 1959 and completed in 1964. It included textbooks, laboratory manuals, teacher's guide, tests, films, and other materials that emphasized the important concepts and generalizations of chemistry, focusing on the chemical processes. This program emphasized students obtaining data from experimental work in the lab where new ideas and questions should most likely develop. The teacher's guide usually suggested the lab exercises before presentation in class so that student would come closer to understanding the nature of scientific investigations and the limitation and uncertainties which exist in each scientific endeavor which they were to learn using the discovery process (Hurd, 1970).

The original CHEM Study lab manual is still available on a limited basis and is still used in selected schools across the country. Although some new manuals have tried to catch some of the flavor of the CHEM Study manual, they fall far short of the original. However, some of the original labs are appearing in more curricula, even including the very traditional ones.

Chemical Bond Approach Project (CBA) was also completed in 1964. It included a textbook, laboratory manual, teacher's guide, and laboratory guide oriented to critical thinking with the student being expected to raise questions. The main goal was to prepare students for the further study of chemistry in college. Problems for study were given in the forms of experiments to be carried out by the student and the student was to use the data collected to develop concepts and theories. This process of developing concepts and theories from data was the emphasis of the curriculum (Hurd, 1970).

These curricula demand much from the teacher. The teacher must create an atmosphere in which the students become active learners and feel confident to observe, experiment, collect data, doubt, hypothesize, test, develop skills of theorizing and learning, participate in class discussion, and exchange ideas with others. The student being the focal point is a radical shift for the teacher and one that has been alarming to many. The process is to be more important than "right" answers, more than one answer may occur, the teacher must listen instead of talking (Hurd, 1984; Shymansky, 1987).

That teacher behaviors are of prime importance was one of the main conclusions of the 1978 report by the National Science Foundation. Most texts discourage inquiry techniques. Even when lab is chosen as an instruction technique, barriers seem to exist. Although teachers would verbally indicate the barriers as funding and physical techniques, the surveys by NSF indicated lack of student motivation and the highly demanding nature of inquiry as perhaps more important (DeRose et. al., 1979).

Furthermore, it is stated in the NSF report, that radical changes had occurred in laboratory work and in the implications for laboratory instruction. Many of the new experiments did not follow the set patterns of previous scientific method approaches. The new curricula emphasized processes. The National Survey showed that only the gifted students profited from the inquiry method but did not attempt to explain why the regular students did not. The report said that the teacher is forced into more open-ended and uncontrolled situations where the students are more likely to raise questions which are more difficult to respond to. Just focusing on the teacher, this means that he must be extremely well-prepared, must focus on directing skills, and must not function as an information disseminator (NSF, 1979).

The NSF report and other recent publications have all contained quotes from the "new curricula" and asked "did they accomplish what they were meant to?" A survey showed a sharp decrease in the use of the curricula almost immediately after they started (Lacy, 1966). Shymansky (unpublished manuscript) studied this phenomenon from which he identified six performance areas focusing on process skills. The percentile composite score with traditional chemistry was 56% compared to 55% with CHEM Study. The percentile process skills score with traditional chemistry was 51% compared to 49% with CHEM Study. He performed similar comparison over other skills and with other of the "new curricula" and found similar results. Perhaps the new chemistry curricula were not as different from the traditional as had been hoped for or as many people believed.

The new curriculum, Chemistry in the Community (ChemCom) was developed by the American Chemical Society. This curriculum is a systems approach using societal issues as a focus. Cooperative learning groups and some laboratory work are used to discover the chemical concepts used in making decisions about the issues. Many assignments are open-ended issues that require a problem-solving approach. This curriculum is only in the primary stages of evaluation. This approach leads to more focus on the student and less on the teacher. This concept will be dealt will more under teacher behaviors.

In summary, the curriculum seems to be an important element in the learning process in that it is often used to determine the focus of instruction in many classes as well as the methodology. However, once again, it is HOW the materials are used that will determine the efficacy and thus the teacher is at the forefront again.

Theoretical Base

Jerome Bruner, Harvard University, is one of the main proponents advocating the discovery method especially in how it motivates further learning. His emphasis is very heavy on the learner. His thoughts were first published about the time of the "new" science curricula of the 1960's and it should be noted that some of these curricula were from the Harvard area. His works, printed in the mid-sixties, closely preceded revisions of some of the curricula. Bruner stated that "the benefit which might be derived from the experience of learning through discoveries that one makes for oneself could be summarized as: increase in intellectual potency, shift from extrinsic to intrinsic rewards, learning the heuristics of discovery, and an aid to memory processing" (Bruner, 1961).

Schwab (1962) then translated Bruner's theory into a teaching strategy where the role of the teacher is "to teach the student how to learn ... his responsibility is to impart to the student an art, a skill, by means of which the student can teach himself." The art component consists in knowing what kind of questions to ask at what point and how the answer may be found. The skill component consists in learning by doing.

On the other hand, Gagne advocated guided learning, where there is much more emphasis on the instructor. Ausubel supports this as does Skinner. Skinner supports it to the extreme, saying that guidance must be so exact that machines are often needed (Clarizo et. al., 1974).

Shulman has compared these two standpoints. He has summed Bruner's stand as stating that the discovery method involves an internal reorganization of previously known ideas in order to establish a better fit between those ideas and regularities of an encounter to which a student has had to accommodate. This follows the philosophy and teachings of Socrates. Shulman goes on to say that Bruner starts with focusing on production and manipulation and tracks a student's progress through three modes of presentation: enactive, ikonic, and symbolic. Such a progression involves the developmental work of Piaget as well. Shulman concludes by saying that Brunner's emphasis is on processes and in improving the student's ability to discover new principles (Shulman, 1968).

Shulman has summarized the work of Gagne by calling it guided learning where the first step is always task analysis of the instructional objectives which must always be specific and behavioral. The analysis is a block building process with facts. Shulman identified the influences on Gagne as being the neo-behaviorist psychological tradition and the task analysis model in military and industrial training. In summary, the objectives of instruction are capabilities that are behavioral products in specified operational terms. Thus, they can be task-analyzed. Emphasis is on knowledge and use of principles (Shulman, 1968).

Another aspect of inquiry strategy is the development of critical thinking, a vital component of producing scientifically literate citizens. Relating to the teacher's role, Lee (1970) summarized:

> In teaching science, we must include consideration of the possible consequences of man's uncritical use of the products of science and technology. And in the process, we must be sure that the differences between science and technology and also the proper and improper uses

of the products of technology are clearly understood by our students.

Shulman's answer was to try and incorporate the best of both viewpoints in a middle-of-the-road theory that he called "guided discovery." He saw "guided discovery" as the best alternative and as being an entirely new psychology developed especially for science and mathematics using the best of both worlds and developing new thoughts and processes for any situation. Too often, the division of opinion has left the classroom teacher in the middle and in confusion over which decision to make. He has made none and reverts to lecturing. Shulman concludes, then, that teacher beliefs and behaviors must be of prime importance (Shulman, 1968).

Trends in Chemical Education

One of the major issues in Chemical Education today is the methodology that should be employed in instruction. To many people, the methodology has not been studied enough. More emphasis is being placed on instruction in articles in the J. Chem. Ed. and in the other periodicals such as ChemUnity, ChemMatters, and all the other affiliated periodicals. Suggestions have been made in ACS position statements and ramifications have been included in the 1977 publication on guidelines for the training of pre-service and in-service teachers.

One of the major methods currently being promoted is use of lecture-demonstration. Although this is not a new idea, new demonstrations, new demonstration methods and techniques, more resources, new training opportunities, and more publicity have brought it to the forefront again. It is not being advocated for everyone. Those students who are planning on being scientists still benefit more from individualized lab instruction. However, that is a small number of students. For the majority of students, the lecture-demonstration method seems best. The major research studies have not "proven" this yet but some argue, it has not been done right yet (Shakhashiri, 1983; Talesnik, 1982).

Advantages to the teacher should be noted to encourage use of the lecture-demonstration method: costs are reduced because of the amount of materials, using demonstrations done on the overhead project allow more visual contact, preparation time is usually less than might be suspected (Alyea's program allows for all solutions for a year to be made in one day), and the safety factors are greatly reduced because only the teacher is handling the materials and then in small amounts (this especially helps in states where OSHA, EPA, and agencies and laws have become very, very strict) (Alyea, 1985).

Instructional advantages should also be provided such as allowing all students to see at once and see the correct results rather than what many see in the ways that they do labs, materials can be more coordinated to lecture materials, students learn better when they can see an actual example of the concept or theory being presented, different learning styles can be met, and attitudinal results may occur (Hunter, 1988).

The disadvantages need to be noted as well. Too many demonstrations have been poorly prepared and poorly executed leading to a "show and tell" or "dog and pony show." Good demonstrations must be designed to encourage students to think (Perkins, 1986; Bent, 1988).

For content, chemistry can be geared more toward descriptive chemistry and the interaction of the chemicals and the everyday world. Often, now, it is so geared to a theoretical base that it has become known as "baby physical chemistry." The controversy over which approach to take has been going on for some time. Researchers need to see if theory is more often memorized and descriptive chemistry learned so that it can be more adapted to practical application and real world experiences or vice versa (Bent, 1988, 1985).

Safety is becoming a bigger and bigger problem in science education. There have been many local, state, and regional conferences and workshops in Ohio, but safety regulations are much worse in other areas of the country where federal agencies are actually monitoring high schools, their facilities, what chemical are used, and how things are disposed of. Although safety concerns are necessary, help and guidelines are needed before some people simply give up. Again, university and industrial ties would be helpful. A teacher needs support from the people within the building and the district as well as universities and industry to manage this growing problem.

Costs may have the greatest impact. It is getting to be critical in all areas of education. The public needs to be educated to the fact that it takes a lot of money and lots more than in the past just to fund a mediocre school. Excellence will take an even greater financial commitment. Science especially needs funding because doing a good job will require a lot of money. Science has the same expenses that all other subjects have in texts, supplies, rooms, etc. but also has the expense of the lab. The role of the lab needs to be evaluated from an educational perspective and not from a purely financial one.

The American Chemical Society has published many pamphlets in an attempt to work with the various aspects involved in chemical education. These include:

1. Educational Services in which audio/visual aids and programs and services are listed,
2. Guidelines and Recommendations for the Teaching of High School Chemistry in which facilities, safety, and professional growth are discussed,
3. Program Summaries,
4. The American Chemical Society and the High School Community which includes a history of involvement with high school chemical education, new concerns, and the offices, departments, and programs to help,
5. Priorities, Partnerships, and Plans: Chemistry Education in the Schools which includes an executive summary, general conclusions, and specific action plans,
6. Guidelines and Recommendations for the Preparation and Continuing Education of Secondary School Teachers of Chemistry.

These all have good ideas and conclusions for the classroom teacher and for teacher trainers among others.

NSTA's series Focus on Excellence Volume 3 Number 2 is about chemistry. It was edited by John Penick and Joseph Krajcik of the Science Education Center at the University of Iowa. From "Ideals in Teaching Chemistry" to "Exemplars in Chemistry: An Analysis", there is a search for excellence in chemistry education. Both inquiry methods and lab activities were identified as being desirable and necessary activities.

Another major part of chemical education today is problem solving. The major person doing research in this area is Gabel. One of her conclusions is that the information processing model and cognitive psychology offer promise in chemistry problem solving for students (Gabel, 1986).

The use of science projects, if properly run to avoid all the pitfalls and problems reported in the literature, is one of the best experiences that a student can have in experimenting for himself on a topic of his own to see where it leads him and how the scientific method can be employed.

The content, the methodology, the instruction, the attitudinal factors, the "experiential-ness", the lab, the instructor, all make a great deal of difference.

Inquiry and Problem Solving

There are many and quite varied definitions of inquiry. It has been defined as the discovery method, the inductive method, the student-centered method, problem-solving, the scientific method, and more. There is also the question of whether it is to be a method or its own goal.

A resource book for teaching thinking Developing Minds was published by ASCD (1985). It is a very generalized book that is more geared to social science courses than science courses.

Schwab(1963) viewed the role of inquiry in science teaching as one which illuminates the scientific framework and the way in which conclusions arise and are tested. Inquiry teaching should allow the student to become aware that science deals with doubts and incompleteness, that it is changed with each new step and advance. He also recommended that lab work should proceed the classroom activities.

This question was continued in a study by Kyle (1980) when he differentiated between inquiry and scientific inquiry. He defined inquiry as asking questions about a topic and scientific inquiry as a progression through a series of steps toward a goal. He chose scientific inquiry as the goal in the classroom and listed competencies students should obtain as well as reasons for them.

Herman (1969) concluded that the results in the literature were conflicting and nonsignificant but he still tended to favor discovery. His tentative conclusions were:

1. Better retention is obtained from rule learning.
2. Better retention is obtained from discovery learning.
3. Discovery learning is relatively more effective as the difficulty of the transfer task increases.
4. Discovery learning is relatively more effective as the period of time between learning and testing on a transfer task increases.
5. Discovery learning is relatively more effective when the learning involves material such as that taught in school.
6. There may be a tendency for discovery learning to be relatively more effective when the background knowledge in a subject is limited.
7. The discovery method is relatively more effective for low ability groups than for high ability groups.
8. After material has been learned by a discovery method, immediate verbalization or further learning adversely affects the original learning.
9. In the discovery method, a reasonable degree of guidance is better than little guidance.

Since then, many studies have been done but not always with the same results. Ladd and Anderson (1970) concluded that a teacher's questioning strategy influences student achievement. Schneider and Renner (1980) found that concrete instruction, as opposed to exposition, produces greater gains in achievement and better retention. Similarly, Champagne and Klopfer (1981) and Snoble (1981) proported inquiry instruction.

The results in the literature have been mixed. Shulman and Keislar (1966) concluded that there was no conclusive evidence for discovery learning but that guided discovery seemed to be best because the learner was forced into an active rather than passive role. Schneider and Renner (1980) found that students experiencing inquiry teaching have greater gains and also develop an increased understanding of the content being taught.

One of the best methods for employing inquiry methodology is through students having the ability to problem transfer and to be able to describe the problem solving in a way that can be measured through protocol analysis. Several of the search methods and heuristics include proximity (hill climbing, means-ends analysis, and random trial and error); pattern matching; and planning. This then transfers to new situations and wider applicability (Yinger, 1984).

Larkins (1980) has defined inquiry as being very difficult because it is hard to teach, leading to difficulties in evaluation and questions of worth; because of the lack of useful input from educational research; and because of a lack of understanding of how inquiry instruction works.

Even within a discipline, results have been confusing. Welch (1972) reported that students in college chemistry classes did not differ significantly in their grades whether they had had a traditional high school class or CHEM Study. Troxel (1968) found that students taking CHEM Study or CBA performed higher in chemistry achievement than students in a traditional course.

A decision must be made as to which hierarchy (Eggen et. al., 1979) or which theory to follow for a particular task. Long term goals must be considered. If students are being trained to be scientists of the future, analytical reasoning and implicit models must be emphasized (Reif, 1980 as referenced in Tuma and Reif, 1980).

The general inductive model has been defined by Eggen et. al. (1979) as having four steps: presenting positive and negative examples; defining a concept; providing practice; and providing feedback. The inductive model is a teaching strategy which uses observations from data, processed by the student, to teach concepts and generalizations. The student does not have prior knowledge of the abstraction but only arrives at it after observing and analysis. New designs need to be sought to incorporate critical thinking skills and processes that can be transferred.

NSTA has attempted to define science as inquiry in its monograph (1983) edited by John Penick. Inquiry classrooms must provide time for science and time for transactions involving reflecting, feeling, and assessing. Even if enough lab time is given, the time for transactions must be given as well. Students must be able to self-evaluate. From there, students must be able to apply and communicate their knowledge. Thus, through doing, students can come to learn the nature of science. Students can only become scientifically literate if they come to personally know how science comes about.

Types of instructional strategies that have been recommended are laboratory work (Bates, 1978); figural analysis (Whimbey and Lochhead, 1984); puzzles and games (Larkins, 1980); cartoons (Roadruck, 1985); logic exercises (Newell and Simon, 1972); and computer simulations (McDermott and Larkins, 1978).

Providing experiences for critical thinking is the teacher's responsibility. Thus, the teacher does make a big difference. The hoped-for outcomes were divided into four clusters:

1. personal needs
2. societal issues
3. fundamental knowledge
4. careers.

In conclusion, the teacher was found to be the critical factor in creating and designing an environment conducive to inquiry. The generalizations that they made from the exemplars studied were that excellent programs teaching science as inquiry:

1. were designed to be excellent
2. involve several years of development
3. are still evolving
4. frequently make use of several years of intensive, focused inservice
5. do not place textbooks in a central position
6. involve a locally developed curriculum
7. have strong administrative and community support and involvement
8. have close ties with post-secondary education
9. have highly energetic teachers who actively participate in professional organizations
10. have very current, knowledgeable, and well educated teachers who have rationales for teaching science. (Yager, 1985)

The question then is "what instructional methods and strategies are viable alternatives?" Yager has said that any method can be viable if the teacher is an exemplar and the biggest factor in this is attending summer programs (Yager, 1984).

CONCEPTUAL CHANGE THEORY

Although some researchers would trace the idea of conceptual change back to the 18th century to Vios and to the early Gestalt psychologists, the work of Piaget in the 1920's and his studies on causality in the 1970's have formed the basis for this theory. A review of research in the area of alternative frameworks by Driver and Easley (1978) and several of the Novak studies (1976, 1979) have helped lay the foundation for the studies in the 1980's.

Probably the most cited article from the 1980's is the 1982 review "Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change" (Posner, Strike, P. Hewson, Gertzog, 1982). This is built on the separate works of Posner, of Strike, and of P. Hewson (1981) and P. Hewson and M. Hewson (1983) in South Africa. The authors define learning as "the result of the interaction between what the students is taught and his current ideas or concepts (Posner et al., 1982, p. 211). They review Piaget from the 1920's to the 1970's; the ideas of scientific misconceptions and alternative frameworks; and ideas of conceptual change. Their question is: how do students' conceptions change when they are confronted with new ideas and new evidence?

The epistemological base starts with the steps in conceptual change in science. Most research is performed in the arena of central concepts or the "hard core" of the science. The second step is when these concepts must be modified. In science, this would lead to a scientific revolution. The same ideas can be used in conceptual changes in learning. Posner et. al. define the corresponding first step in learning as assimilation and the second as accommodation. The big difference between the steps in science and the steps in learning is that in learning one must also account for the learner's current concepts. This joining of accommodation and the learner's current concepts leads to conceptual change.

When does accommodation occur and what features cause this change to be made and to be retained? The four most prevalent conditions seem to be:

1. There must be dissatisfaction with existing conceptions.
2. A new conception must be intelligible.
3. A new conception must appear initially plausible.
4. A new concept should suggest the possibility of a fruitful research program. (Posner et. al., 1982, p. 214)

The learner's current concepts will influence which new concepts he will consider. The following are important in determining the direction of an accommodation.

> 1. Anomalies: The character of the specific failure of a given idea is an important part of the ecology which selects its successor.
> 2. Analogies and metaphors: These can serve to suggest new ideas and to make them intelligible.
> 3. Epistemological commitments:
>   a. Explanatory ideals: Most fields have some subject matter-specific views concerning what counts as a successful explanation in the field.
>   b. General views about the character of knowledge: Some standards for successful knowledge such as elegance, economy, parsimony, and not being ad hoc seem subject matter neutral.
> 4. Metaphysical beliefs and concepts:
>   a. Metaphysical beliefs about science: ...
>   b. Metaphysical concepts about science: ...
> 5. Other knowledge:
>   a. Knowledge in other fields.
>   b. Competing concepts: One condition for the selection of a new concept is that it should appear to be more promising than its competitors.
>
> (Posner et. al., 1982, p. 214)

People will resist changing their frameworks unless they are dissatisfied (Posner et. al., 1982) or in a state of disequilibrium (Piaget, 1974). There appear to be five ways that a concept may become plausible.

> 1. One finds it consistent with one's current metaphysical beliefs and epistemological commitments, i.e., one's fundamental assumptions.
> 2. One finds the concept to be consistent with other theories or knowledge.

3. One finds the concept to be consistent with past experience.
4. One finds or can create images for the concept, which match one's sense of what the world is or could be like.
5. One finds the new concept capable of solving problems of which one is aware (i.e. solving the anomalies).

(Posner et. al., 1982, p. 218)

A new concept is unlikely to be assimilated unless problems are found with an old concept. These problems have been called "recalcitrant data" by Lakatos (1970) and "difficulties" by Posner et. al. (1982). Posner et. al. (1982) proposed that in science, anomalies may provide the cognitive conflict that will lead to accommodation. However, conceptual change still may not occur. There are several possibilities:

1. rejection of observations
2. lack of concern with experimental findings because they are seen as irrelevant to one current concept
3. compartmentalization of knowledge to prevent new information from conflicting with existing belief ("Science has nothing to do with the real world")
4. an attempt to assimilate the new information into existing concepts.

Student dissatisfaction would occur only if:

1. Students understand why the experimental findings represent an anomaly
2. Students believe that it is necessary to reconcile the findings with their existing concepts
3. Students are committed to the reduction of inconsistencies among beliefs they hold
4. Attempts to assimilate the findings into the students' existing concepts are seen not to work.

Since it is so difficult to achieve these, few students find their concepts disturbed by anomalies.

(Posner et. al., 1982, p. 221)

Teaching chemistry provides a rational basis for conceptual change. Accommodation may cause these changes but they are difficult to cause. Many anomalies will not be seen as such without a thorough understanding of the theory in which the experiment is performed. Therefore, a teacher must be ready to change the content of the course to provide the following conditions:

> 1. More emphasis should be given to assimilation and accommodation by students of that content than to content coverage.
> 2. 'Retrospective anomalies' should be included, particularly if historically valid anomalies are difficult to comprehend, or were not responsible for driving the conceptual change in the first place.
> 3. Sufficient observational theory should be taught for students to understand the anomalies employed.
> 4. Any available metaphors, models, and analogies should be used to make a new concept more intelligible and plausible.
>
> (Posner et. al., 1982, p. 225)

For teaching strategies, they suggested:

> 1. Develop lectures, demonstrations, problems, and labs which can be used to create cognitive conflicts in students. Among other things, one might consider what types of homework problems would create the kind of conflict necessary as preparation for an accommodation, and whether labs could be used to help students experience anomalies (Stavy & Berkowitz, 1980).
> 2. Organize instruction so that teachers can spend a substantial portion of their time in diagnosing errors in student thinking and identifying defensive moves used by students to resist accommodation.
> 3. Develop the kinds of strategies which teachers could include in their repertoire to deal with student errors and moves that interfere with accommodation.
> 4. Help students make sense of science content by representing content in multiple modes (e.g.,verbal, mathematical, concrete-practical, pictorials), and by helping students translate from one mode of representation to another (Clement, 1977).
> 5. Develop evaluation techniques to help the teacher track the process of conceptual change in students (e.g., the Piagetian clinical interview) (Posner & Gertzog, 1982).
>
> (Posner et. al., 1982, p. 225-226)

Thus, the teacher's role is not to only present information or clarify ideas but to become:

> 1. An adversary in the sense of a Socratic tutor. In this role, the teacher confronts the students with the problem arising from their attempts to assimilate new conceptions.
> 2. A model of scientific thinking....
>
> (Posner et. al., 1982, p. 226)

This is probably the most critical reference in citing the teacher's role in creating anomalies to cause accommodation so that true learning can occur.

A conference was held at Cornell University on this area of research (Helm and Novak, 1983) focusing on student misconceptions in nine main areas. Most of the papers presented were further elaborations of the work of the four authors of Posner et. al., of the work of Nussbaum, and of the work of Novak.

Nussbaum and Novick (1982) also promoted the use of alternative frameworks as proposed by Driver and Easley. They began with a review of terms starting with Dewey in 1910 building to cognitive dissonance by Festinger, disequilibrium by Piaget, accommodation that they attributed to Ausubel, and the work of Driver and Easley. Their steps in instructional strategy for facilitating accommodation are:

1. (a.) Create an "exposing event" which requires students to invoke their preconceptions in order to interpret it.
   (b.) Encourage students to describe their preconceptions verbally and pictorially.
   (c.) Assist students in stating their ideas clearly and concisely, thereby making them aware of the elements in their own "alternative frameworks" (preconceptions).
   (d.) Encourage confrontation in which students debate the pros and cons of their different preconceptions and increase their own awareness and understanding of the differences between their own "frameworks" and those of their classmates.

2. Create a "discrepant event," one which creates conflict between exposed preconceptions and some observed phenomenon which they cannot explain.
3. Support students' search for a solution and encourage emerging accommodation. Encourage students to articulate and elaborate the desired conception when it is proposed.

(Nussbaum and Novick, 1982, p. 188)

A follow-up and extension of the work of Posner et. al. was published in 1986 by Hashweh (1986) based on studies in Israel. His purpose was to insure concept stability. Hashweh found Piaget's equilibrium/disequilibrium theory, Schema theory, and the work of Runelhart as a start but still not enough. His criticism of Posner et. al. was that a distinction was not made between the psychological processes and the external conditions related to them. Thus, he identified the factors necessary to be identified as the factors relating to the persistence of the preconception; those relating to the acquisition of new concepts; and those relating to cognitive restructuring. Factors affecting the first one include: experience and repeated use; development by experience; finding the easiest way to equilibrium; understanding through schemata or mapping; other variables; and cultural beliefs, language, and common sense epistemology. The teacher is often unaware of these preconceptions and often evaluations do not show preconceptions or incorrect assimilations and thus, needs to be aware of each of these. Factors affecting the second one include: the need for new schema to be created; and the purpose of the concept perceived by the student. The teacher then needs to know the concept; get students to use previous knowledge to start a new framework; use concrete examples; use analogies; and use examples. The main factor affecting the third is the lack of enough research using common definitions. The teacher needs to create chances for students to reinterpret experiences, extend knowledge, and clarify doubts.

In a second follow-up article, Hashweh (1988) called for separating future research studies of students' conceptions in science into three areas. The first would be a descriptive area that would identify and describe preconceptions. The second would be explanatory which would study ways to explain conceptual stability and change. The third would be studies to foster conceptual changes which would test the explanations offered in the second case.

A new model, the Constructivist Learning Model (CLM), has been proposed using these precepts. Yeany has endorsed it as a focusing point for science education research for the 1990's because it connects research and exemplary practices. In this theory, there are four main foci: the processor (usually the students), the problem, the responses, and the results. Often in this approach, a group of two or three students work on the problem. The strategies are: invitation, exploration, proposing explanations and solutions, and taking action. Learning becomes the process of self-organization and reorganization. The CLM could then become a model used in pre-service and in-service education of teachers especially in emphasizing conceptual change (Yager, 1991).

TEACHING BEHAVIORS

Horton's study of 1981 started by looking at an historical perspective of studies of teacher characteristics starting with Ryan's of 1960. He continued with other studies of the 1960's. From the 1970's, he cited the study of Wilson and Garibaldi (1976) as being the first report of the positive impact of NSF-sponsored institutes; he cited the work of Nieft and Lashier (1975) who had found a positive correlation between teacher warmth and student achievement and attitudes; and cited the work of Clark (1975) who had found a positive relationship between teacher cognitive characteristics and student performance. Horton also cited studies that showed no significant relationships with some of the same variables thus showing that nothing definite is known and the need for more research to be done.

Lawrenz (1975) used two statistical procedures to examine the relationship between student and teacher characteristics. All conclusions were seen as tentative and formulative and included:

1. A high relation between teachers' scores on the Science Process Inventory and student achievement and attitude.
2. A class that is goal-directed has high student achievement. However, this should not become formalized into strict rules as this causes an inverse effect.
3. A teacher's desire for self-improvement was found to be the most consistent predictor of high student outcomes.
4. The teacher's personality is one of the most significant variables relating to student outcomes.

A teacher who has a class of high achieving students is often ambitious, hard-working, works on improving techniques, is confident, has definite goals, is flexible, and has a classroom environment that is less strict and more apt to be changeable.

Several studies have looked at similar research. Large surveys with many tables of teachers characteristics have been made including Hirsch (1984), Yager and Penick (1984), Horak and Lunetta (1979), Bybee (1978), and Rothman (1969). Aiello-Nicosia et. al. (1984) found that the teacher's ability to control variables is a more valuable characteristic than the understanding of science processes for student achievement. A meta-analysis by Druva and Anderson (1983) showed a low relationship between teacher background characteristics and student outcomes. Another study (Bonnstetter, 1983) examined a profile of excellent teachers and found that they are:

1. older,
2. more experienced, and
3. better educated.

The first two were seen to imply greater professionalism and the fact that this excellence takes time to nurture and the need for numerous support structures including: administrative, community, parents, and fellow teachers. The most important aspect of education seemed to be how recently a course had been taken. In addition, factors indicated were making presentations and extra curriculars like advising science clubs. The overall model is one of involvement, dedication, and enthusiasm.

A five-part study was carried out at North Carolina State University to assess the academic preparation of North Carolina science teachers (Anderson, 1981). This study was precipitated by the need to improve the status of science teaching in the schools for the 1980's by having the schools be able to attract and retain qualified science teachers. Although the chemistry teachers were found to <u>average</u> 17.2 semester hours of chemistry, 32.6% had less than 9. The relationship between academic preparation and school size was significant at the 0.05 level leading to the conclusion that larger schools with several sections of chemistry were able to employ a chemistry teacher whereas smaller schools had to have teachers fill in across their areas of specialization. The final conclusions were:

1. Teachers should teach only their specialization.
2. Renewal work (6 hrs. every 5 years) would be mandatory.

3. At the pre-service level, more candidates need to be attracted to the physical sciences.
4. Continuous in-service to up-date teachers is vital.

Stake and Easley (1978) found that teachers felt trapped and felt that there were no options open to them. They felt helpless and bound to finish the text and were resigned to the status quo. Students feel this also and react by feeling trapped and that the classroom is dull and no fun.

From the results of recent meta-analyses of instructional strategies, some direction has been found in what are effective classroom practices. The first by Boulanger (1981) studied the period of 1963-78 with students in 6th - 12th grade. Through a count of instructional strategies as the independent variables, he identified from 51 studies six instructional clusters related to cognitive outcomes. The cluster that produced the most significant gains was the use of pre-instructional strategies such as behavioral objectives, advanced organizers, or set instruction. He also found that greater realism or concreteness of supporting instructional materials was associated with greater cognitive achievement.

A second large meta-analysis, conducted by Wise and Okey as part of the University of Colorado Science Meta-Analysis Project (1983), was conducted to synthesize findings about the effects of various teaching strategies on science achievement. Through analysis of 160 studies, 12 categories of teaching techniques were identified. The most significant items they found were: wait-time, use of focusing techniques, and manipulation.

Inquiry teaching and learning have been prevalent issues in science education literature of the past century. The results of four meta-analysis studies point to positive results from inquiry teaching (Anderson, 1983). These studies indicated that curriculum materials developed with an inquiry philosophy were more effective than most critics were willing to admit. Wise and Okey (1983) also found an increase in cognitive outcomes when inquiry-discovery strategies were used.

A meta-analysis on the effects of different instructional systems, by Willett, Yamashida, and Anderson (1983), showed both mastery learning and personalized systems of learning (Keller Plan) to be superior. Dillashaw and Okey (1983) found the effects of mastery learning strategy modified to limit diagnosis to two cycles/unit of instruction to have significant results with high school chemistry students. The study indicated that teachers may be more willing to spend time constructing formative or progress tests using remediation if only two cycles can increase student achievement.

Another meta-analysis to identify the effects of different pre-service and inservice teachers training approaches (Sweitzer, 1982) looked at inquiry teaching but the main conclusions were on methodology and the problems encountered when trying to compare variables because the variables were not defined closely enough to each other.

How do science teachers see themselves? Lawrenz (1975) looked at several variables and asked teachers to rate them. In her study, all the ratings for teaching ability variables were above satisfactory. However, she said these must be viewed in light of possible biases and large individual variability. The conclusions she drew were:

1. Senior high teachers may appreciate extra help in the area of individual instruction;
2. Teachers rated themselves consistently high in subject matter knowledge;
3. There is a perceived need for improvement in time, space, and personnel conditions.

NSTA has developed a series of pamphlets for self-assessment. Volume 2 of the Guidelines for Self-Assessment of Secondary School Science Programs is for science teachers. The characteristics identified as being critical were:

1. science background and general education,
2. professional education,
3. professional activities and development,
4. contribution to the profession,
5. attitudes,
6. student and teacher perceptions of teacher professionalism, and
7. teacher recruitment and selection policies.

What, then, does this imply for the teacher either in pre-service or in the classroom? Teachers need to be trained specifically for non-lecture techniques. The best programs seem to be NSF courses geared toward this (Blosser, 1981) but these are few and far between and the selection process is not always straightforward.

CONCEPTUAL CHANGE STRATEGIES of TEACHING

Conceptual change strategies of teaching are ones in which students' conceptions in science are challenged. There is an event which causes students to want to change their previous conceptions. Students must verbalize what their concepts were, what they are, and their thought process in changing them. This is based on the theory of conceptual change of Posner et al. (1982).

Nussbaum and Novick (1982) presented a case study of lessons on the particle concept and analyzed the use of cognitive accommodation as a strategy. They based their work on the alternative framework theory of Driver and Easley (1978). In this theory, students' alternative frameworks may play a critical interfering role in the learning process. This interference often leads teachers to believe that the student is not understanding when the student actually is understanding incorrectly. Therefore, more time must be spent in the process of the teacher understanding what concepts the student is learning. In their review of the literature, Nussbaum and Novick note that the learner must feel dissatisfaction with existing held concepts or the learner will not change. This leads to one of the key parts of their vision of conceptual change: this dissatisfaction must be created but often is not. To achieve this dissatisfaction, there must be a devised event capable of promoting exposure of the preconception of the student and the student must articulate this preconception. This is their second key element: the student must articulate the preconception and the new conception, and the thought process in changing between the two conceptions. In summary,

> 1. (a.) Create an "exposing event" which requires students to invoke their preconceptions in order to interpret it.
>   (b.) Encourage students to describe their preconceptions verbally and pictorially.
>   (c.) Assist students in stating their ideas clearly and concisely, thereby making them aware of the elements in their own "alternative frameworks" (preconceptions).
>   (d.) Encourage confrontation in which students debate the pros and cons of their different preconceptions and increase their own awareness and understanding of the differences between their own "frameworks" and those of their classmates.
> 2. Create a "discrepant event," one which creates conflict between exposed preconceptions and some observed phenomenon which they cannot explain.
> 3. Support students' search for a solution and encourage emerging accommodation. Encourage students to articulate and elaborate the desired conception when it is proposed.
>
> (Nussbaum and Novick, 1982, p. 188)

Hashweh (1986) stated that the practical problem facing teachers is getting the student to change from an alternative concept to the scientifically accepted concept. This takes place in a three step process: the old concept is discarded, a new concept is accepted, and the new concept must be usable in new examples. The factors most affecting lack of concept change are teachers being unaware of the students' conceptions and that evaluation methods do not measure concepts. Suggestions that Hashweh gave for changing concepts are: giving examples and non-examples of the concept to be developed and using analogies to the concept to be taught and then developing schema for them. In these suggestions, at least two examples of each type must be used. He further stated that students will retain the new concepts better if they see a purpose for them. The strengthening of the concept comes from discussion and debate when students can reinterpret experiences and clarify doubts. The teacher should then provide opportunities for enrichment that emphasize the new concept.

Basili and Sanford (1991) tested conceptual change using small cooperative learning groups based on the theories of Slavin. In their study, the groups were given focusing tasks as a strategy for fostering conditions for conceptual change. The group examined members' misconceptions which were identified using concept maps. Student have to explain their own maps and then the group had to develop one map to turn in. A control group was used that had all of the same instruction except for no small group work. The posttest evaluation sought to evaluate concepts and the experimental group had a statistically significantly lower ($p < 0.05$) proportion of misconceptions for four of the five concepts. They attempted to find behaviors that helped or hindered the small group processing and found that discussion helped the process. Hindering factors were found to be: flawed understanding of some of the basic science terms being used, students' view that their primary task was to finish the assignment for a grade, and groups that had too dominant a leader. Other positive variables that they identified were seeing physical examples and asking questions that linked the new concept to "the real world".

While studying elementary students, Stavy (1991) drew some different conclusions. She suggested that a better path was to build upon students' correct conceptions rather than trying to change incorrect ones and expanded her educational implication by stating that examples must be used to support these correct intuitive preconceptions. When a new concept is to be taught, the teacher should begin with an example for which there is maximal reinforcement of the preconceptions and then move into more abstract areas using analogies. The key, though, she states is to have students express their ideas.

Robertson (1989) reported in a NARST Research Matters to the Science Teacher article, that the best student problem solvers are ones that have their concepts integrated into a knowledge base. His suggestions for conceptual understanding include having the teacher help the students see the "big picture" of how the subject concepts connect with one another and with everyday experiences, focusing on the big picture so that some exercises become second nature and trivial, making students want to understand rather than memorize, testing on the ability to solve similar problems instead of like problems, and allowing time to acquire conceptual understanding.

Kyle and Shymansky (1989) said that teaching for conceptual change requires a teaching strategy where students are given time to identify and articulate their preconceptions, time to investigate the validity of their preconceptions, and time to reflect upon and reconcile differences. The teacher must discover students' preconceptions before instruction, provide motivating experiences related to the concept, facilitate student discussion, and provide opportunities to use the new concepts. Learning becomes the process of interaction between the students' thinking and the teacher provided stimuli.

Elements are the same between Conceptual Change Strategies and both the Suchman Model and the Taba Model. In the Suchman Model, there are similarities in that there is the use of the steps in the scientific method to solve the "problem" and that the problem being used must be one that motivates the students. The big difference is that in the Suchman Model the data gathering must be simulated and in Conceptual Change Strategy of Teaching that is but one of the ways that data could be attained. This pattern is shown below (as cited in Joyce and Weil, 1972).

Suchman's Model

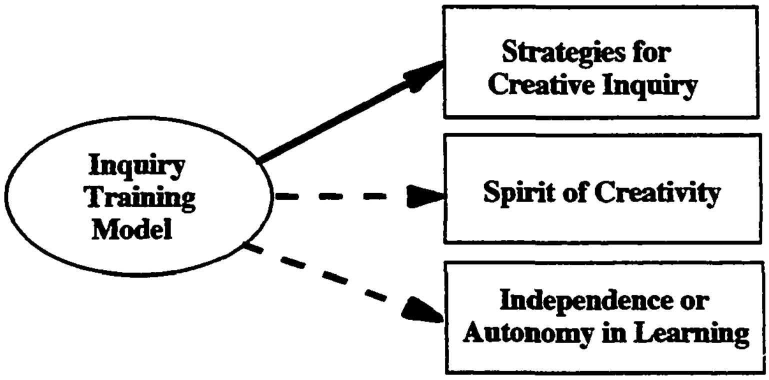

Figure 2. Suchman's Model.

The unstructured Taba Model of teaching also has characteristics of The Conceptual Change Strategy of Teaching. The first three parts of her model of listing, grouping, and labeling are ways of assessing student background knowledge, preconceptions, or misconceptions. These steps, coupled with the continuing steps of data collecting, generalizing, comparing, and predicting, also follow the steps of the "scientific method." Some of the questioning methods Taba had developed were further described and elaborated upon by Joyce and Weil (1972). Taba's tables from The Teacher's Handbook for Elementary Social Studies, 1967 (as cited by Joyce and Weil, 1972) show the steps.

TABA MODEL

Concept Formation

Overt Activity	Covert Mental Operations	Eliciting Questions
1. Enumeration and listing.	Differentiation.	What did you see? hear? note?
2. Grouping.	Identifying common properties, abstracting	What belongs together? On what criterion?
3. Labeling, categorizing.	Determining the hierarchical order of items. Super- and sub-ordination.	How would you call these groups? What belongs to what?

Source: Hilda Taba, Teacher's Handbook for Elementary Social Studies, 1967, Addison-Wesley, Reading, Mass.

Interpretation of Data

Overt Activity	Covert Mental Operations	Eliciting Questions
1. Identifying points. Listing.	Differentiating.	What did you notice see? find?
2. Explaining items of identified information.	Relating points to each other. Determining cause.	Why did so-and-so happen?
3. Making inferences.	Going beyond what is given. Finding implications, extrapolating.	What does this mean? What picture does it create in your mind? What would you conclude?

Source: Hilda Taba, Teacher's Handbook for Elementary Social Studies, 1967, Addison-Wesley, Reading, Mass.

Application of Principles

Overt Activity	Covert Mental Operations	Eliciting Questions
1. Predicting consequences. Explaining unfamiliar phenomena. Hypothesizing.	Analyzing the nature of the problem or situation. Retrieving relevant knowledge.	What would happen if?
2. Explaining items of identified information.	Relating points to each other. Determining cause.	Why did so-and-so happen?
3. Making inferences.	Going beyond what is given. Finding implications, extrapolating.	What does this mean? What picture does it create in your mind? What would you conclude?

Source: Hilda Taba, Teacher's Handbook for Elementary Social Studies, 1967, Addison-Wesley, Reading, Mass.

The Suchman Model also delineates the steps in the inquiry training model especially from the standpoint of the role of the teacher (Joyce and Weil, 1972).

Anderson (1987) has developed a hierarchy in which "teaching science for understanding" is the main goal. Subsumed under this method is the method of "strategic teaching" and a subset of that method is the conceptual change strategy. He has listed the steps in planning for conceptual change as:

PLANNING GUIDE FOR TEACHING FOR CONCEPTUAL CHANGE

STUDENT THINKING	TEACHING STRATEGIES
<u>Preparation for Conceptual Change</u>	
Anticipate learning to take place	Provide advanced organizers
Develop adequate descriptions of natural phenomenon	Generate observation, discussion, and writing about everyday objects and events
Develop awareness of, and dissatisfaction with, own explanations	Question and debate explanations Generate observation and discussion of discrepant events
<u>Introduction of Scientific Conceptions</u>	
Achieve initial minimal understanding of scientific explanations	Emphasize key principles and theories Contrast misconceptions and and goal conceptions
Understand scientific conceptions as reasonable alternatives to own reasoning (not too difficult to understand, not just additions to their own ideas)	Introduce conceptions in the context of meaningful tasks
<u>Application and Integration</u>	
Understand scientific principles and theories as widely applicable.	Explicitly signaled inclusion of conceptions in other tasks, especially:
Understand interconnections with other personal and scientific ideas	-tasks in everyday contexts -tasks in other scientific contexts

In summary, The Conceptual Change Strategy of Teaching proceeds through several steps. A teacher must assess conceptions before instruction, provide examples to challenge the conceptual framework, must provide examples which link the framework to the "real world", and, most importantly, allow time for concept assimilation by allowing time for students to articulate their understanding.

SUMMARY

How do people learn? If it is by a series of encounters that are easily assimilated, education would be easy. However, if a disequilibrium is created, how is it to be overcome and will the accommodation be a stable change? Questions also arise over how methods will be used. Teaching with toys may be a method but how will the toys be used and what questions will be asked?

The Learning Cycle and the Constructivist Theory seem to offer new insights into the necessary elements of a good lesson. First, there must a focus. Second, there must be an exploratory phase that is activity oriented. This can take many forms including discrepant events. Only then is the concept introduced. Finally, there is a concept application phase. Most lessons have focused only on step three leading to many misconceptions and to little retention (Barman and Kotar, 1989).

Concern has arisen on the parts of some people that more focus on the experimenting aspects will cause teachers to become scientists first and lose sight that their "experiment" is on people first and science second. Others have concerns that teachers do not know what the scientific method is (Yager, 1985, Hurd, 1984). To help both of these concerns, a list by Yager (Yager, 1985) was made to help the teacher follow the scientific method but always realizing that people are involved. The teacher thus:

1. Observes pupils and their development.
2. Perceives his teaching in a problematic fashion.
3. Establishes goals and objectives.
4. Makes careful curriculum plans for teaching and learning.
5. Utilizes effective methods and techniques for teaching and learning.
6. Uses the best possible evaluative instruments for collecting information.
7. Keeps careful accounts of students' behavior changes and progress.
8. Diagnoses pupils' learning problems.
9. Measures pupils' learning progress.
10. Analyzes test results and other observational data.
11. Makes predictions about pupils' learning possibilities.
12. Guides pupils for correct placement.

Many of the research implications can be summarized by stating a very qualified teacher with diverse abilities with strong background in management behaviors, educational psychology, theories, historical perspectives, and scientific method skills is needed. The role of the teacher is emphasized in NSTA's monograph on <u>Conditions for Good Science Teaching</u> with twenty-four pages of recommendations for conditions.

More research is needed to know what conditions <u>do</u> work. More importantly, if the teacher is <u>THE KEY</u>, much more needs to be known about the teacher and the intersection with the subparts of this chapter.

What are the implications for instructors? Students could memorize the steps of the processes of learning but still not know how to use them. Hurd (Hurd, 1984) has stated that students can apply these steps and show true learning only when they see a concrete example to which to apply the steps. If a student figures out how a rubber band wheel works but cannot transfer this information, there is little purpose. If a student figures out mass changes during burning but cannot deduce what happens in other similar chemical processes, the point is lost except as a one-time fact. The processes need to be transferable. College instructors also need to know how their students learn and how to teach teachers how to evaluate the learning process.

If Kimball (1968) is correct in his findings that the concept of the nature of science and its processes are established by the end of undergraduate training, teacher training programs need to have all possible positive elements including use of The Conceptual Change Strategy of Teaching.

Reconciling the literature review and the problem of teaching with the strategy of conceptual change, a lesson using The Conceptual Change Strategy of Teaching may include:

1. Assessing preconceptions

   -using a pre-test OR

   -asking for predictions for a reaction OR

   -asking for the definition of certain concepts

2. Presenting an exposing event

   -presenting a discrepant event in the form of a demonstration, video presentation, or lab activity in order to invoke student preconceptions to interpret it in the light of their current conceptions

Note: There needs to be a high level of interest on the part of the students. The teacher must get their attention so they will think about the event instead of just passively watching it. If students need a prod in speaking, the teacher can ask for observations of what was seen and, also, ask for explanations.

3. Describing of students' thought processes

-describing what they are thinking verbally, pictorially, or charting in the individual form of a concept map, a Vee diagram, drawing pictures of what has happened, discussing it with the class, or working in cooperative learning groups

Note: This is one of the keys to the CCST process where students describe what they are thinking in some form that the teacher can understand and that the student is fully aware of their own thinking.

4. Forming and sharing of students' hypotheses

-forming of hypotheses by students about the reasons behind the how and why of the event used

-sharing of their ideas by students with other students in the class

-defending their thought processes by defending their views, debating pros and cons, furthering their descriptions, or adding to their new concepts

5. Providing application

-testing of students' concepts with new situations

-discussing students' newly emerging viewpoints

Note: The more practically oriented the new situations, the more likely the students will be to retain the new concept because they see a purpose to it.

These steps are condensed into chart form below. The steps have also been compared to the steps of the scientific method referring back to the concerns of some researchers that the nature of science and the use of the scientific method must be employed for students to learn the concepts of science rather than just memorizing them.

Conceptual Change Strategy of Teaching

Phases	The Teacher	The Student
1.) Assessing preconceptions	1.) Uses a pre-test Asks for predictions for a reaction Asks for the definition of certain concepts	1.) Focuses on the topic
2.) Presenting an exposing event	2.) Presents a discrepant event, to challenge conceptual framework Asks eliciting questions	2.) Interprets results
3.) Describing of students' thought processes	3.) Asks students to describe thought processes verbally or pictorially	3.) Describes current thought processes
4.) Forming and sharing of students' hypotheses	4.) Provides a free forum Help students state hypotheses Provides forum for debate or lab situation to test hypotheses Asks questions as needed Encourages elaboration	4.) Forms hypotheses Elaborates upon hypotheses Shares ideas Defends thought processes
5.) Providing application	5.) Provides new, practically oriented situations in everyday contexts and in new science contexts Tests students' concepts with new situations Discusses students' newly emerging viewpoints	5.) Tests hypotheses Adopts new concept

CHAPTER III

EXPERIMENTAL METHODOLOGY

This chapter consists of several components. An overview of the study and its purpose is given. The methods of survey research are overviewed. The research questions are stated. Finally, the experimental design is described, including the study design, a description of the population, the method of designing the instrument, validity and reliability determinations, and data analysis approach.

STUDY OVERVIEW

This was a descriptive study that looked at "what is going on out there." Specifically, the percentage of high school chemistry teachers responding to the instrument who use The Conceptual Change Strategy of Teaching in their classrooms was determined. Additionally, their reasons for using The Conceptual Change Strategy were surveyed.

The success of the study was measured in four major ways:

1. by defining The Conceptual Change Strategy of Teaching and developing a checklist for use of The Conceptual Change Strategy of Teaching in the classroom and achieving agreement with Conceptual Change Strategy experts;
2. by developing the instrument to test for use of The Conceptual Change Strategy of Teaching which included how to develop a test for the usage of The Conceptual Change

Strategy of Teaching and how to test for the usage of The Conceptual Change Strategy of Teaching from a distance;

3. by surveying high school chemistry teachers in southwestern Ohio and having the majority of the instruments returned;
4. by gaining some insight into why teachers use or do not use The Conceptual Change Strategy of Teaching so that a more definitive follow-up study could be performed in this area.

Public education in the 1990's faces a new focus on accountability especially as seen in test scores and other evaluation methods. The public is concerned about "their scores" whether that be the U.S. versus other countries, their state versus another state, or their school district compared to another. Organizations both within and without the education sector are looking at ways to improve education and the tests scores. The Association for Supervision and Curriculum Development (Executive Director Gordon Cawetti, 1991) has outlined seven areas in which to work:

1. School Restructuring
2. Cooperative Learning
3. Effective Practices for At-Risk Students
4. Collaborative Supervision
5. Authentic Assessment of Student Learning
6. Interdisciplinary Education
7. Teacher Methodology especially Teaching Students to Think.

This is but one example of ideas to improve education. However, one concept that is central to all ideas about educational reform is the need to have students who can think for themselves.

With some of the current confusion of educational priorities, a teacher must be prepared to understand which methods and strategies will work best in the classroom setting. Students come to chemistry class with certain ideas, expectations, and concepts already in place. Learning may take place in the intersection of this preconceived state and what is being taught. If teachers can predict when this learning may occur and under what situations this likelihood may be increased, learning may be increased and facilitated.

Using the Learning Cycle and the idea of teaching for conceptual change is one that has been used for many years and is once again being proposed with the addition of a focusing event at the beginning of the instructional cycle. The use of this method may place the teacher in a role similar to Socrates and this can become a frightening proposition to many teachers. It means the teacher must be well versed in the chemistry and its theory, in the Learning Cycle and idea of conceptual change, in problem solving protocols, and be comfortable in the role of facilitator rather than leader or director. In The Conceptual Change Strategy of Teaching the steps of the Learning Cycle are used as well as additional the steps that require students to explain what they are thinking, either verbally or in some written form.

What do practicing teachers actually do to cause conceptual change instead of rote teaching? Statistics have been quoted to the effect that teachers spend between 90-95% of the time using their textbooks. Is this caused by too little preparation in the field they are teaching so that they must rely so heavily on the book, or is it caused by a perpetuation of the only teaching method they have seen when they were students? The role of teacher is a vital one and characteristics of teachers who are using different approaches need to be identified so that these characteristics could be used to create courses and methodologies for both pre-service and in-service teachers. Many researchers have said that improvement depends on the teacher and the methodology. The answer to improvement will be a wide and complex one. One area upon which to focus is to see where we are now and whether The Conceptual Change Strategy of Teaching is being used in the area of southwestern Ohio. In this study, a survey instrument was used to determine what percentage of the high school chemistry teachers in the greater Cincinnati area use The Conceptual Change Strategy of Teaching.

SURVEY RESEARCH

In this study, a survey instrument was developed and sent to the high school chemistry teachers in the Greater Cincinnati area in the Ohio counties of Hamilton, Butler, Clermont, and Warren. The sample survey is one of the newer and important methods of research in the social sciences (Rossi, Wright, and Anderson, 1983). The sample survey is a systematic and standardized approach to the collection of data on individuals, households, or other groups through the questioning of an identified sample. The earliest form of survey research was done in ancient times in the periodic census taking. Nineteenth-century surveys also covered basic demographics but also added employment information. The first change from the basic census format came after World War I with the introduction of consumer marketing research. The last element to be added was on the issue of probability sampling with Princeton University being one of the first universities to use survey research in the 1930's. The U.S. Government became involved during World War II. The 1950's was a time for two major national survey organizations affiliated with universities and the development of private firms such as the Nielson Company.

The 1960's was the beginning of today's survey methods because of three major advances: computers to analyze data; the role of the federal government both in its use of the method and in its financing many studies; and combining surveys with other methodology. The 1970's saw a continuance of these trends except that funding radically fell off by the end of the decade and there was decline in overall response rates. In the 1980's an estimated $2.5 billion was spent on various forms of survey research. The greatest number of surveys was probably conducted by the federal government but the greatest amount of money was spent by the private sector in particular by the Nielson Corporation. The mass media and academic sectors came in third and fourth (Rossi, Wright, and Anderson, 1983).

Dillman's "The Total Design Method" (Dillman, 1978) outlines how to perform a mail survey and many of the pitfalls of which to be aware. This method has been used mainly in statewide mailings asking for opinions on certain issues. This was especially prevalent in the early 1970's and use of the method by Dillman and others has led to many improvements of the method.

Survey research is a method gaining in popularity and in acceptance in research circles. For this study, the survey method was a satisfactory method because the attempt was being made to elicit information about strategies used in the classroom with no evaluative comments on the strategies.

RESEARCH QUESTIONS

1. Is it possible to devise a definition of The Conceptual Strategy of Teaching?
2. Is it possible to transform the definition of The Conceptual Strategy of Teaching into a survey instrument?
3. Are there high school chemistry teachers in southwestern Ohio using The Conceptual Strategy of Teaching?
4. Is there enough information at this point to gain some insights into why certain teachers use The Conceptual Change Strategy of Teaching?

EXPERIMENTAL DESIGN

Phase I: Definition and Checklist

The first goal of this study was to define The Conceptual Strategy of Teaching and to prepare a checklist for use of this strategy. This was accomplished through a synthesis of the literature review. The checklist is included in the summary of Chapter II. The definition was more difficult. The Conceptual Change Strategy of Teaching is one in which steps of many teaching strategies are used but the unique feature is that students must verbalize their thought processes at each step along the way in a manner in which the teacher can monitor the thinking process. This takes place in a learning situation where the student starts with a misconception or no conception about the topic and through a series of responses to an exposing event forms and defends hypotheses and ends by testing the new conception in new situations. Again, the key part is not only to form these hypotheses but to describe the thought processes along the way. The interaction of the teacher's role and the student response is what makes this a new strategy of teaching which is beyond the current literature emphasis on conceptual change from a theoretical basis.

Phase II: Development of the Survey Instrument

The second goal of this study was to develop a self-reporting, valid and reliable survey instrument (Appendix A) that could be used to see if a population of high school chemistry teachers are using The Conceptual Strategy of Teaching.

The process of developing the instrument took more than a year as various aspects were fine tuned both to the theoretical basis and to a form that would elicit the greatest response. The process started by looking at as many different studies as possible involving conceptual change strategy. These were reported in Chapter II. In summary, most of the studies were at the very first stages, involved small groups under direct observation, and dealt mainly with trying to establish what were the necessary components of conceptual change approach.

A trial instrument was sent to a small group of teachers in order to learn more about surveying techniques. The knowledge gained was used in deciding how to construct the final instrument.

Various forms of asking questions and developing scenarios were discussed with the graduate advisor. The biggest problem was how to ask if a teacher was using The Conceptual Change Strategy of Teaching on a self-reporting instrument without directly asking. It was decided to use a series of scenarios where one in each set employed The Conceptual Change Strategy of Teaching and one did not. However, each scenario had to use good and doable teaching strategies and have a good chance of success. Teachers would be asked which they would use in ideal situations to see if the teacher had a conceptual change orientation. Additionally, as a follow-up, in case some other mitigating factors affected a choice, a survey section was included which described the components of a lesson and asked respondents to rank their importance. Lesson components were developed that included all of the usual approaches such as lecture and assessment as well as those that have recently appeared in the literature such as cooperative learning as well as the ones unique to The Conceptual Change Strategy of Teaching. There should be a high relationship between the scenarios chosen and the lesson components chosen. This approach was discussed with the members of the research committee. As a result, a third section was added to determine if beliefs caused different choices to be made. The ideas incorporated into the third section of the survey were a combination of suggestions of the research committee and findings from the literature review. Care was taken to balance the number of choices from various standpoints representing the major pressures that a teacher might feel.

A series of meetings was held with consultants of the University of Cincinnati Institute for Policy Research (Carrozza and Smith, 1993). Their expertise is in instrument design. Their suggestions included a reformatting of the scenarios but basically leaving them intact, redoing the lesson components into a three section ranking, and redoing the belief statements into a five-point Likert scale. It was recommended that two more sections be added. One section was to ask for some information about the teacher filling in the survey and one section was to provide for a free response. The instrument was rewritten with these changes and after being checked by the Institute for Policy Research, was sent to the research committee members for input and suggestions. Most suggestions at this point were minor.

The instrument was sent to twelve science educators from around the country representing educators at the high school and college level, in colleges of education and departments of chemistry, all of whom had a minimum of one graduate degree and all but two have doctorates. These experts were asked to critique the instrument to see if it tested what it was designed to test, was each question valid and needed, were choices doable and believable, and were any major areas left out. Of the eleven reviewers who responded, ten thought it sufficiently described the strategy and the eleventh said it did not fit with all of his ideas about the theory of conceptual change but did not elaborate. However, the purpose of this study was not to describe everything about the theory of conceptual change but only to use part of the theory to develop the new Strategy of Teaching. Since ten of the eleven reviewers who responded felt the chart met its goals, it was concluded that this purpose was completed. The reviewers were asked specifically about four sets of lesson scenarios. A few minor content changes were suggested for the sets on the periodic table, the gas laws, and acids and bases. A fourth set, on polymers, had been written. The majority of the reviewers liked this set but felt that too few teachers may teach the topic. Suggestions were made on physical format such as having all choices being the same length and there being a consistent place to indicate a choice. These suggestions were incorporated into the final scenarios. On Part 2: Everyday Strategies, the reviewers thought the necessary components were present. Many expressed concern about ranking 14 items in section three but the consultants at the Institute for Policy Research still insisted that that was acceptable. On Part 3: Reasons Behind Your Choices, the reviewers felt that two items were ambiguous and they were eliminated from the final form. There were few comments on Parts 4 and 5. The reviewers also had a chance to critique the cover letter. The original cover letter said the instrument would take 10-15 minutes and several of the reviewers thought this was too optimistic.

These changes were incorporated into the next draft which was resubmitted to the Institute for Policy Research and the research committee. It was also submitted to Dr. Janet Bohren, Chair of the Human Subjects Review Committee for the University of Cincinnati College of Education for her committee's approval and critique. Several suggestions were made for the cover letter. The proper forms were completed and filled.

At this point, it was felt that a self-reporting, valid instrument had been created. It was copied and prepared for mailing.

Phase III: Administering the Survey Instrument

One of the consultants at the Institute for Policy Research had also recommended the book by Dillman, Mail and Telephone Surveys: The Total Design Method (Dillman, 1978), as a guideline for the logistics of mailing the survey. This book included suggestions for cover letters, follow-up mailings, best days of the week for mailing, and other practical suggestions.

By approval of the Board of Directors of the Cincinnati Section of the American Chemical Society, the ACS mailing list of the high school teachers in the Greater Cincinnati area in the Ohio counties of Hamilton, Butler, Clermont, and Warren counties was used. This list included 162 names. It was later found that 18 of these names were invalid due to closing of schools, retirement of teachers, or teachers being reassigned and not being replaced. This left a population of 144 teachers.

The first mailing was sent with a cover letter (Appendix B) explaining how and when to return the instrument, the instrument, and a return envelope. The return envelopes were number coded (as part of the suggestions in The Total Design Method) to check off which instruments were returned. After 17 days, a postcard (Appendix B) reminder was sent to teachers who had not yet responded. Two weeks after that, a third mailing was sent with a new cover letter (Appendix B), an additional copy of the instrument, and another return envelope.

In all, 75 of the 144 instruments were returned for a return rate of 52.1%. The consultants at the Institute for Policy Research and the literature review had indicated that a usual response rate was 10-15% with 20% being considered excellent. The very high response rate of 52.1% was higher than normally expected for a mailed survey. This could have been because of the topic, because of the use of The Total Design Method, because of teachers wishing to express their opinions, or because teachers wanted to help. There is no way of concluding which of these was a more dominant cause or if they were all equally at work.

The part of the population that responded the least were from small Christian schools. It is not known if this is because they do not have chemistry teachers or if they chose not to respond. When there were three or more teachers in one building, often one did not respond. Other than that, there was no pattern to the responses.

Phase IV: Interpreting the Results

The results of survey instrument indicated a 32 to 42 split between those teachers with a conceptual change orientation and those who did not. This relatively high use would indicate that The Conceptual Change Strategy of Teaching is a method of which teachers are aware and of which they find useful to use. An inspection of the respondents on their scenario choices showed a consistency in their selections across all three choices. The data analysis methodology is described later in this chapter. The statistical results are reported in Chapter IV and the conclusions are made in Chapter V.

Defining the Populations

The sample for this study consisted of the 144 high school chemistry teachers in the Greater Cincinnati area in Ohio in Hamilton, Clermont, Butler, and Warren Counties. The schools represented by these teachers included public, private, and parochial; various sizes; and various locations ranging from urban to suburban to rural.

Data Analysis

Data analysis was performed at the University of Cincinnati Institute for Policy Research using SPSS/PC+ using multiple t-tests. The Bonferroni Inequality correction could be made for a tighter alpha $0.05 / 8 = 0.006$ due to the possibility of a Type 1 error caused by the sample size and multiple t-tests. The tight control of the Type 1 error could lead to a greater chance of Type 2 error. Hence, the powers were calculated at an alpha of 0.05 and placed on the data tables. These statistical results are shown in Chapter IV and the conclusions are listed in Chapter V.

Upon further reflection, it was decided that teachers' beliefs might be more indicative of their orientation that their choices on scenarios. This was performed as an ad hoc analysis and the results are reported in Chapter V. Respondents were separated into new Groups based on their ratings on Part 3: Reasons Behind Your Choices. Items [4], [7], [12], [14], and [16] were placed on the instrument as beliefs indicative of The Conceptual Change Strategy of Teaching teachers and [9], [10], [13], and [15] were added as opposite beliefs. To place teachers in their new Groups, teachers who had rated the first group with 4's and 5's (but not all 4's) and had also rated the second set as 3 or lower were placed into new Group 1 and labeled the Believers. This was 23 teachers (31%). The other teachers were placed in new Group 2 and labeled the Non-believers. This was the remaining 51 teachers (69%). Analyses were run with these new Groups and these results are discussed in Chapter V.

CHAPTER IV

EXPERIMENTAL RESULTS

Data analysis began as soon as some of the instruments were returned. The codes on the envelopes were used to check off respondents. In all, 75 of the 144 instruments were returned for a return rate of 52.1%. The consultants at the Institute for Policy Research and the literature review had indicated that a usual response rate was 10-15% with 20% being considered excellent. The very high response rate of 52.1% was higher than normally expected for a mailed survey. This could have been because of the topic, because of the use of The Total Design Method, because of teachers wishing to express their opinions, or because teachers wanted to help. There is no way of concluding which of these was a more dominant cause or if they were all equally at work.

The part of the population that responded the least was small Christian schools. It is not known if this is because they do not have chemistry teachers or if they chose not to respond. When there were three or more teachers in one building, often one did not respond. Other than these trends, there was no apparent pattern to the responses.

PART 1: LESSON SCENARIOS

Choices in this part of the survey form (Appendix A) were used to separate the 75 respondents into two groups. One group had chosen at least two of the three CCST scenarios and the other group had chosen one at the most. This separation was made to get two groups and based on the fact that one scenario may have been chosen for reasons other than a teacher's usual orientation of instruction. Of the 75 respondents, one was unusable because too many blanks were left. The results for each scenario for the remaining 74 respondents is shown in Table I. This divided the responding teachers into 32 CCST (43%) and 42 non-CCST (56%) (see Table II). Later, it was found that 3 of the non-CCST group had left too many blanks to be used in all parts and were discarded. The t-test values are based on the 71 remaining. The results of survey instrument indicating a 32 to 42 split between those teachers with a conceptual change orientation and those who do not have this orientation suggests that The Conceptual Change Strategy of Teaching is an instructional method of which teachers are aware and which at least some find useful to use.

Table I. Choices on Lesson Scenarios.

Lesson 1: Periodic Table	
Scenario 1 - non-CCST lesson	34 teachers
Scenario 2 - CCST lesson	39 teachers
Lesson 2: Gas Laws	
Scenario 1: CCST lesson	21 teachers
Scenario 2: non-CCST lesson	53 teachers
Lesson 3: Acids and Bases	
Scenario 1 - non-CCST lesson	35 teachers
Scenario 2 - CCST lesson	36 teachers

Table II. CCST Choices on Lesson Scenarios.

CCST Lessons Chosen	Teachers	Percent
3	12	16%
2	20	27%
1	20	27%
0	22	30%

PART 2: EVERYDAY STRATEGIES

This part of the instrument (Appendix A) was a ranking. The lower the mean, the more preferred the strategy. The results of the data could be reported in several different methods. One was by frequency counts. These frequency counts are subdivided by the two groups established in Part 1. The frequency counts showed that there is not a consensus on any item for either group but patterns could be seen in whether an item was highly or lowly ranked. (This data was not included.)

Next, the overall means, the means for Group 1 initially labeled as The Conceptual Change Strategy of Teaching teachers, the means for Group 2 initially labeled as the non-Conceptual Change Strategy of Teaching teachers, the level of significance, and the powers were calculated for each item on the instrument. The means were calculated showing the overall mean and standard deviation as well as the means and standard deviations for each group. This was used when entering the data to calculate the powers. Tables III - V show the instrument with the means and powers for each item on the instrument. In the tables, the first column shows the overall mean from each item, "m 1" is the mean from Group 1, "m 2" the mean from Group 2, p is the level of significance, and the power displays the power of the t-test for each item. The overall mean is also a method of looking at preferred strategies. In this form, the lowest overall mean for Part 2: Everyday Strategies, is interpreted as the most preferred strategy. So in Section 1: An Introduction to a Unit, the most preferred strategy was item [5], *an attention-grabbing demonstration.* The least preferred strategy was item [8], *to have students read and outline the chapter.* In Section 2: Within a Unit, the most preferred strategy was item [3], *to have students perform lab*

Table III. Group Means for Introduction to a Unit.

mean	m 1	m 2	p	power at 0.05	
5.1	5. 7	4.7	0.047	0.47	[1] ... list behavioral objectives before beginning unit
3.1	3.6	2.6	0.013	0.66	[2] ... oral overview of what ... learning in the unit
6.0	6.2	5.8	0.479	0.10	[3] ... written pre-test of knowledge of a topic ...
5.0	5.2	4.8	0.324	0.17	[4] Provide advanced organizers ...
1.9	1.7	2.0	0.451	0.45	[5] Start ... with an attention-grabbing demonstration
4.3	3.5	4.8	0.004	0.80	[6] Start the unit with a lab experiment
4.2	3.2	4.9	0.000	0.94	[7] ... students describe what ... know about a topic ..
6.5	6.8	6.3	0.249	0.19	[8] Have students read and outline the chapter

Table IV. Group Means for Within a Unit.

mean	m 1	m 2	p	power at 0.05	
8.3	11.1	6.1	0.000	0.98	[1] Lecture using an overhead projector or chalkboard
7.4	7.4	7.4	0.992	0.03	[2] Have students form and defend hypotheses
3.0	3.6	2.6	0.077	0.44	[3] Have students perform lab experiments
4.2	5.0	3.5	0.017	0.65	[4] Do demonstrations
9.2	10.5	8.3	0.004	0.75	[5] Use computer simulations
10.5	11.6	9.7	0.010	0.70	[6] Assess frequently such as with daily quizzes
7.6	8.8	6.7	0.014	0.64	[7] Use ... technology to show everyday examples
7.3	7.2	7.4	0.791	0.04	[8] Use simulations ... students predict outcomes
8.0	7.0	8.8	0.026	0.60	[9] Have students explain discrepant events
7.2	5.6	8.4	0.004	0.82	[10] ... complete open-ended lab exercises
7.3	6.2	8.1	0.030	0.58	[11] ... small groups ... equal responsibilities
7.4	5.3	9.1	0.000	0.93	[12] ... cooperative learning groups ... roles defined
7.4	7.4	7.4	0.945	0.03	[13] ... class discussions on topic and related issues
10.1	7.9	11.8	0.000	0.97	[14] ... students describing their thought processes ...

Table V. Group Means for the Conclusion of a Unit.

mean	m 1	m 2	p	power at 0.05	
6.3	6.5	6.2	0.459	0.11	[1] ... essay test on the material presented
5.8	7.0	4.9	0.000	0.97	[2] ...objective test on the material presented
3.2	4.1	2.6	0.002	0.85	[3] ... mixed format test on the material presented
6.0	5.3	6.5	0.000	0.92	[4] ... essay test on the material ... in new contexts
5.4	5.4	5.4	0.891	0.03	[5] ... objective test on the material ... in new contexts
3.1	2.4	3.7	0.000	0.92	[6] ... mixed format test ... in new contexts
3.2	3.0	3.3	0.530	0.09	[7] ... test that has written and practical parts
2.9	2.3	3.4	0.038	0.51	[8] ... test has written, simulation, and practical parts

experiments. Item [6], *assessing frequently*, was the least preferred. In Section 3: Conclusion of a Unit, the most preferred assessment technique was item [8], *a test with written, simulation, and practical parts.* The least preferred method was item [1], *an essay test on the material presented.* Specific details of the way in which the two Groups differed is discussed in Chapter V.

PART 3 : REASONS BEHIND YOUR CHOICES

This part of the instrument made use of a rating scale. The higher the mean, the more important that statement was as to why a teacher chose the strategies ranked in Part 2: Everyday Strategies. The results of the data can be reported in several different ways. One of the first methods was by frequency counts. The frequency count for Part 3: Reasons Behind Your Choices showed that most people tended to rate all items highly. It is not known whether this is a tendency in general, whether the respondents think everything is very important, or if there was a reluctance to rate any item low because of "how it might look."

Next, the overall means, the mean for Group 1 initially labeled as The Conceptual Change Strategy of Teaching teachers, the mean for Group 2 initially labeled as the non-Conceptual Change Strategy of Teaching teachers, the level of significance, and the powers were calculated for each item on the instrument. The means were calculated showing the overall mean and standard deviation as well as the means and standard deviations for each group. This was used when entering the data to calculate the powers. Table VI shows the results from Part 3 of the instrument (Appendix A) with the means and powers. The overall mean is again a way of determining preferred reasons. The higher the rating, the more preferred the reason. The highest rated one was item [2], *students need applications in a lesson* and item [2], *students need motivational activities.* The lowest rated reason was item [15], *students learn best by being told the facts, being told them again, and being told again.*

Table VI. Reasons Behind Your Choices.

mean	m 1	m 2	p	power at 0.05	
4.5	4.4	4.5	0.693	0.06	1.) Students need motivational activities
4.5	4.4	4.5	0.333	0.16	2.) Students need applications in a lesson
4.0	4.1	4.0	0.593	0.08	3.) ... need to explore an idea to whet their appetites
4.3	4.6	4.1	0.000	0.93	4.) Students need to interpret ideas for themselves
2.8	2.7	3.0	0.171	0.26	5.) ... fit with the requirements of my department
3.4	3.4	3.5	0.552	0.08	6.) These choices fit with ideas about which I have read
4.4	4.4	4.3	0.509	0.10	7.) ... need to have a thought provoking demonstration and /or lab to stimulate their explanation of phenomenon
2.2	2.0	2.5	0.058	0.45	8.) ... fit the preferred lesson format of my principal
3.6	3.4	3.7	0.307	0.17	9.) Students need to be focused on the topic first.
3.4	2.8	3.9	0.000	0.97	10.) Students need a strong framework to organize their learning and they need to be told what they will be learning
2.3	1.8	2.6	0.002	0.82	11.) These choices reflect an approach parents like
3.8	4.2	3.6	0.002	0.83	12.) ... need to form and defend their own hypotheses
4.0	3.9	4.1	0.311	0.18	13.) ... need help in discovering & organizing concepts
4.2	4.4	4.1	0.040	0.54	14.) ... need to learn to verbalize their thought processes
2.0	1.5	2.3	0.000	0.91	15.) Students learn best by being told the facts, being told them again, and being told again.
3.9	4.1	3.7	0.037	0.52	16.) ... need to test their hypotheses in new situations
2.4	1.8	2.8	0.000	0.95	17.) These choices reflect the way in which I was taught
3.1	2.6	3.4	0.014	0.70	18.) These are effective choices because I have seen them presented by persons whose opinions I respect.

DIFFERENCES BETWEEN THE TWO GROUPS

The next step of the analysis of the data was to start looking at difference between the two groups. Starting with Group 1, at this point labeled as The Conceptual Change Strategy of Teaching Teachers, they ranked item [5], *starting with a demonstration*, as the most preferred strategy for starting a unit, followed by item [7], *having students describe what they know.* Item [5], *the demonstration*, is the same for both groups but this preference for item [7], *having the students describe what they know*, is unique to Group 1. The two least preferred strategies are the same for both groups. For Section 2: Within a Unit, the two most preferred strategies are the same for both groups, item [3], *doing labs* and item [5], *demonstrations.* After that, though, the preferences change. Group 1 ranked item [12], *cooperative learning groups,* next followed by item [10], *open-ended lab exercises.* The two least preferred strategies were item [1], *lecturing* and item [6], *assessing frequently.* In Section 3: Conclusion of a Unit, Group 1 ranked item [8], *testing with written, simulation, and practical parts,* first and item [6], *mixed format tests with the material in new formats,* second. Item [2], *objective tests on the material presented,* was ranked as least preferable. On Part 3: Reasons Behind Your Choices, ratings were made. The most highly rated reasons were item[4], *students need to interpret ideas for themselves,* item [7], *students need a thought-provoking demonstration or lab to stimulate their explanations of phenomenon,* and item [1], *students need motivational activities.* The lowest rated ones were choices *fit with the principal* item [8], *fit with parents* [11], or *fit with how the teacher was taught* [17] as well as item [15], *students learning best by being told the facts over and over.*

Group 2, labeled as non-conceptual change strategy teachers at this point in the analysis, ranked item [5], *starting with a demonstration*, as the most preferred strategy for starting a unit, followed by item [2], *having the teacher give an overview of what the students would be learning in the unit.* Item [5], *the demonstration*, is the same for both groups but this preference for item [2], *having the teachers describe what is going to happen*, is unique to Group 2. The two least preferred strategies are the same for both groups. For Section 2: Within a Unit, the two most preferred strategies are the same for both groups, item [3], *doing labs* and item [4], *demonstrations.* After that, though, the preferences change. Group 2 ranked item [1], *lecturing*, next. This is quite different as it was one of the lowest preferred strategies for Group 1. Next was item [7], *the use of technology to show examples.* The two least preferred strategies were item [6], *assessing frequently,* and item [14], *having students describe their thought processes,* which is definitely different than a conceptual change strategy orientation. In Section 3: Conclusion of a Unit, Group 2 ranked item [3], *testing with mixed format tests on the material presented*, first and item [7], *written and practical parts,* second. The big difference here was that Group 1 had chosen testing methods that used new contexts and Group 2 had chosen testing methods on the material presented. Item [1], *essay tests*, were ranked as least preferable. In summary, the most highly rated reasons were item [2], *students need applications,* and item [1], *students need motivation.* The lowest rated ones were item [8], *choices fit with the principal* and item [15], *students learning best by being told the facts over and over.* These reasons were similar for both groups

PART 4: PROFILE

The profile part of the instrument (Appendix A)included questions about length of time teaching, numbers of classes and preparations, educational degrees, and professional organizations and presentations. Both Groups were almost identical in the ranges that they showed on all items. Each Group had teachers who had taught from one year to thirty-plus years. Each Group teachers with four to six classes. There was a wide range of degrees in both Groups with each having bachelor's and master's degrees in sciences, education, and other fields. Teachers listed a wide range of professional organizations and presentations from zero to all organizations and zero to forty-plus presentations in each Group. Teachers were categorized in several different ways but no patterns or relationship with Group 1 or Group 2 membership were found. The results did show that a wide cross-section of teachers had responded to the survey.

PART 5: MITIGATING FACTORS

Most teachers put something in the free response blank of the instrument (Appendix A) but usually it was only a few words. Typical answers were ones predicted by the literature - "shortage of money," "shortage of time," and "student apathy." Other responses were "numbers of preparations," "high absenteeism among students," "lack of support," and "lack of energy." There was no apparent distinction between the two Group 1 and Group 2 respondents. Despite the typical answers teachers entered in this Part, more subtle factors showed up in the personal interviews and in the results from Part 3: Reasons Behind Your Choices. This is discussed in Chapter V.

CHAPTER V

CONCLUSIONS

This was a descriptive study looking at what teaching strategies are being used by high school chemistry teachers in the Southwestern Ohio counties of Hamilton, Butler, Clermont, and Warren as revealed by a survey instrument. Specifically the instrument was designed to determine if The Conceptual Change Strategy of Teaching was being used. The four purposes of this study were: to define The Conceptual Change Strategy of Teaching and to develop a checklist for use of The Conceptual Change Strategy of Teaching in the classroom and to achieve agreement with Conceptual Change Strategy experts; to develop a self-reporting, valid and reliable survey instrument to determine the use of The Conceptual Change Strategy of Teaching from a distance; to survey and have the majority of the instruments returned; and to gain sufficient information in follow-up study to begin to gain some insights into why teachers use The Conceptual Change Strategy of Teaching.

Chapter V is organized in a series of sections. The first section is a four part series looking at the four purposes of the study. These purposes are:

1. To devise a chart for the Conceptual Change Strategy of teaching;
2. To develop a self-reporting, valid and reliable survey instrument of high school chemistry teachers and their teaching strategies;
3. To administer the survey and to have a majority returned;
4. To gain insights into why teachers use the conceptual change strategy of teaching.

In the discussion of the last purpose, the results of the survey are discussed in detail, especially the differences between the two groups identified as Learner-directed Teachers and Teacher-directed Teachers. After this purpose section follows a summary and discussion that looks at interpreting the results of the study. Then, an ad hoc analysis focusing on teacher beliefs was performed and the results and discussion are included. Overall conclusions are based on the results of the study. The conclusions are then listed specifically both relating back to the purposes and to the study as a whole. The purposes are limited by the scope of the study and these limitations are discussed next. Finally, implications are drawn from these conclusions.

PURPOSE 1: TO DEVISE A CHART FOR THE CONCEPTUAL CHANGE STRATEGY OF TEACHING

There were four main purposes of this study. The first was to develop a chart showing the steps in The Conceptual Change Strategy of Teaching. This was accomplished through the literature review and merging different theories and ideas of various researchers. An important study on conceptual change theory was by Posner et al. in 1982. In their theory, they described conceptual change strategies as ones in which students' conceptions in science are challenged. There is an event which causes students to want to change their previous conceptions. Students must verbalize what their concepts were, what they are, and their thought process in changing them. Nussbaum and Novick (1982) presented a case study of lessons on the particle concept and analyzed the use of cognitive accommodation as a strategy. They based their work on the alternative framework theory of Driver and Easley (1978). The first key element is a devised event capable of promoting exposure of the preconception of the student and the student must articulate this preconception. The second key element is that the student must articulate the preconception and the new conception, and the thought process in changing between the two conceptions. Hashweh (1986) suggested that the best ways to cause concept change are: giving examples and non-examples of the concept to be developed and using analogies to the concept to be taught and then developing schema for them and that students will retain the new concepts better if they see a purpose for them. The strengthening of the concept comes from discussion and debate when students can reinterpret experiences and clarify doubts. Basili and Sanford (1991) tested conceptual change using concept maps using small cooperative learning groups based on the theories of Slavin . Students had to explain their own maps and then the group had to develop one map to turn in. Stavy (1991) suggested that a better path was to build upon students' correct conceptions rather than trying to change incorrect ones and expanded her educational implication by stating that examples must be used to support these correct intuitive preconceptions. When a new concept is to be taught, the teacher should begin with an example for which there is maximal reinforcement of the preconceptions and then move into more abstract areas using analogies. The key, though, she states is to have students express their ideas. Kyle and Shymansky (1989) said that teaching for conceptual change requires a teaching strategy where students are given time to identify and articulate their preconceptions, time to investigate the validity of their preconceptions, and time to reflect upon and reconcile differences. The teacher must discover students' preconceptions before instruction, provide motivating experiences related to the concept, facilitate student discussion, and provide opportunities to use the new concepts. Learning becomes the process of interaction between the students' thinking and the teacher provided stimuli. Anderson (1987) developed a hierarchy in which "teaching science for understanding" is the principle goal.

Subsumed under this method is the method of "strategic teaching" and a subset of that method is the conceptual change strategy. His steps were outlined in Chapter II. In summary, The Conceptual Change Strategy of Teaching proceeds through several steps. A teacher must assess conceptions before instruction, provide examples to challenge the conceptual framework, must provide examples which link the framework to the "real world," and, most importantly, allow time for concept assimilation by allowing time for students to articulate their understanding.

A chart was developed to show The Conceptual Change Strategy of Teaching. This chart (Table VII), and the instrument that was developed, were sent to twelve reviewers with expertise in science education. Of the eleven reviewers who responded, ten thought it sufficiently described the strategy and the eleventh said it did not fit with all of his ideas about the theory of conceptual change but did not elaborate. However, the purpose of this study was not to describe everything about the theory of conceptual change but only to use part of the theory to develop the new Strategy of Teaching.

Part of the first purpose of the study also was to develop a specific working definition. The Conceptual Change Strategy of Teaching is one in which steps of many teaching strategies are used, but the unique feature is that students must verbalize their thought processes at each step along the way in a manner in which the teacher can check. This takes place in a learning situation where the student starts with a misconception or no conception about the topic and through a series of responses to an exposing event, forms and defends hypotheses and ends by testing the new conception in new situations. Again, the critical component is not only to form these hypotheses but to describe the thought processes along the way. Most of the literature has focused on

Table VII. Conceptual Change Strategy of Teaching.

Phases	The Teacher	The Student
1.) Assessing preconceptions	1.) Uses a pre-test Asks for predictions for a reaction Asks for the definition of certain concepts	1.) Focuses on the topic
2.) Presenting an exposing event	2.) Presents a discrepant event, to challenge conceptual framework Asks eliciting questions	2.) Interprets results
3.) Describing of students' thought processes	3.) Asks students to describe thought processes verbally or pictorially	3.) Describes current thought processes
4.) Forming and sharing of students' hypotheses	4.) Provides a free forum Help students state hypotheses Provides forum for debate or lab situation to test hypotheses Asks questions as needed Encourages elaboration	4.) Forms hypotheses Elaborates upon hypotheses Shares ideas Defends thought processes
5.) Providing application	5.) Provides new, practically oriented situations in everyday contexts and in new science contexts Tests students' concepts with new situations Discusses students' newly emerging viewpoints	5.) Tests hypotheses Adopts new concept

conceptual change as a theory and not the implementation of the theory. This study is focusing upon the interaction of the teacher's role and the expected student response. This focus on conceptual change as a teaching strategy and not just a theory is what makes this study unique and beyond the current literature emphasis on conceptual change as a theoretical basis.

PURPOSE 2: TO DEVELOP A SELF-REPORTING, VALID AND RELIABLE SURVEY INSTRUMENT OF HIGH SCHOOL CHEMISTRY TEACHERS AND THEIR TEACHING STRATEGIES

The second of the four main purposes of this study was to develop a self-reporting, valid and reliable survey instrument to test for use of The Conceptual Change Strategy of Teaching. This was accomplished using the literature review, specifically the components that the theorists said were important to causing concept change, and experts in instrument formation.

The steps of The Conceptual Change Strategy of Teaching were used to develop three lesson scenarios on the topics of the periodic table, gas laws, and acids and bases. Alternative lesson scenarios were developed that incorporated good lesson methodology but not those of The Conceptual Change Strategy of Teaching. Care was given to describing lessons that would take approximately the same length of time to teach. The lessons needed to be good and doable.

Part Two, Everyday Strategies, was developed to show the individual lesson components of "starting a unit", "within a unit", and "evaluating a unit" written with the steps developed in The Conceptual Change Strategy of Teaching. Other choices were added that were components of a lesson taught from a more teacher-directed method than those for the conceptual change method. A few extra choices were added as potential reasons to gain some insights into why a teacher does or does not have a conceptual change orientation.

Part Three, Reasons Behind Your Choices, was developed to see if patterns could be found in the differences between teachers who chose The Conceptual Change Strategies of Teaching and those who did not.

The instrument was developed and then reviewed by four members of the faculty of the University of Cincinnati who are experts in educational methodology and/or chemistry. Then, the instrument was sent to twelve other reviewers from other institutions across the country. The willingness of the reviewers to critique the instrument and to provide prompt responses greatly enhanced the process. The staff at the University of Cincinnati Institute for Policy Research were an invaluable resource. Such research help is vital for this method of research.

PURPOSE 3: TO ADMINISTER THE SURVEY INSTRUMENT and TO HAVE A MAJORITY RETURNED

The survey was mailed to 162 high school chemistry teachers in the Southwestern Ohio counties of Hamilton, Butler, Clermont, and Warren. It was found that 18 of these could not be contacted due to the closing of schools, maternity or sabbatical leaves, or retirements and teachers not being replaced. Of the 144 left, 75 were returned for a return rate of 52.1%. The response rate of 52.1%was higher than normally expected for a mailed survey. This could have been because of the topic, because of the use of the Total Design Method, because of teachers wishing to express their opinions, or because teachers wanted to help. There is no way of concluding which of these was a more dominant cause or if they were all equally at work.

The part of the population that responded the least were from small Christian schools. It is not known if this is because they do not have chemistry teachers or if they chose not to respond. When there were three or more teachers in one building, often one did not respond. Other than this pattern of lack of response, there was no other apparent pattern to the responses or the lack of responses.

Part of the purpose of this study was also not only to create the instrument and to have a representative proportion returned but also to find teachers who would choose The Conceptual Change Strategy of Teaching so that differences between the two groups could be analyzed. Teachers were divided into groups based on their choices on Part 1 of the instrument, the lesson scenarios. Choices in this part were used to separate the respondents into two groups. One group had chosen at least two of The Conceptual Change Strategy of Teaching scenarios and the other group had chosen one or none. This separation was made to identify two groups. This separation was also based on dividing the teachers based on what was interpreted as their usual orientation, that of teacher-directed teaching or learner-directed teaching. This suggestion was made by the consultants at the University of Cincinnati Institute for Policy Research. The consultants felt that one choice could always have been made based on a teacher's special method of presenting a favorite topic or a desire not to teach one topic. They felt that having a "leeway" of one choice would still show predominant orientation. Therefore, one Group had chosen two or three of the scenarios developed from The Conceptual Change Strategy of

Teaching standpoint and the other Group had chosen at the most one of these scenarios.

Of the 75 respondents, one instrument was unusable because most of it was left blank. Later, it was found that three other teachers had left too many blanks to be used in all parts of the study and were discarded. The remaining respondents were divided into 31 teachers in Group 1 (44%) and 40 teachers into Group 2 (56%). Group 1 was eventually labeled as the learner-directed teachers and Group 2 labeled as the teacher-directed teachers. The data was entered into a computer and analyses run by consultants in the University of Cincinnati Institute for Policy Research.

PURPOSE 4: TO GAIN INSIGHTS INTO WHY TEACHERS USE THE CONCEPTUAL CHANGE STRATEGY OF TEACHING

Part 1: The Lesson Scenarios

Choices in this part were used to separate the 75 (52%) respondents into two groups. Group 1 had chosen at least two of The Conceptual Change Strategy of Teaching scenarios and Group 2 had chosen one at the most. This separation was made to get two groups and this method of separation was recommended by the consultants at the University of Cincinnati Institute for Policy Research so that two groups of teachers would be identified based on what the consultants felt would be the teachers' usual orientation of more toward type 1 or type 2. The labeling of the groups was left off by the consultants. Of the 75 instruments returned, one was unusable because too many blanks were left. The 74 remaining divided into 32 (43%) in Group 1, a conceptual change orientation and 42 (57%) into Group 2, those without a conceptual change orientation. After first dividing the groups, Group 1 was named CCST and Group 2 was named non-CCST. Later, Group 1 was renamed as the Learner-directed Teachers and Group 2 was renamed as the Teacher-directed Teachers. This renaming is discussed in the Summary and Discussion section.

Part 2: Everyday Strategies

The next part of the instrument focused on the specific strategies a teacher would use in everyday lessons. It was divided into three sections: the introduction to a unit, strategies within a unit, and strategies at the conclusion of a unit. Each section was rank ordered in order of preference for that strategy. The next three sections of this chapter deal with each section of the instrument individually. In each section, m1 refers to the mean for the Group 1 teachers, labeled at this point as the CCST teachers (the Conceptual Change Strategy of Teaching teachers) and m2 refers to the mean for the Group 2 teachers, labeled at this point as the non-CCST teachers.

Part 2: Everyday Strategies - Section 1: Introduction to a Unit

The Conceptual Change Strategy of Teaching, as developed in the Chart form, would indicate that the first step in developing a new lesson would be to assess the preconceptions held by the learners. Item [7], *having students describe what they know about a topic*, was found to be significantly more preferred ($p=0.000$) by the Group 1, CCST teachers. It was their second most preferred strategy ($m1 = 3.2$). This showed that the CCST teachers in Group 1 did find this as an important method of starting a unit. However, in Section 2, Within a Unit, this method dropped in preferred ranking when compared to other methods.

The second step of The Conceptual Change Strategy of Teaching is for the teacher to present an exposing event to challenge the learner's conceptual framework. The most preferred method of starting a unit for the CCST teachers, was item [5], *start the unit with an attention-grabbing demonstration* (m1 = 1.7). This was not significantly different from the non-CCST teachers (p=0.451). This does not add to the knowledge about the CCST teachers, as the statement does not imply how the demonstration was used and no statistical difference is seen from the non-CCST teachers. Item [6], *start with a lab experiment*, was ranked with the third most preferred method for starting a unit by the CCST teachers, (m1 = 3.5) and was significantly different (p=0.004) from the non-CCST teachers.

From the opposite standpoint, the CCST teachers would not be expected to ask students to outline a chapter (m1 = 6.8) or tell students what they would be learning (m1 = 5.7).

For starting a unit, the non-CCST teachers, would be expected to tell students what they would be learning. Item [1], *give the students a list of behavioral objectives before beginning the unit*, was significantly more preferred by the non-CCST teachers than the CCST teachers (p=0.047). Item [2], *give an oral overview of the unit*, was also significantly more preferred by the non-CCST teachers than the CCST teachers (p=0.013).

The conclusion at this point was that the two Groups, the CCST teachers and the non-CCST teachers, did show significant differences in how they would start a unit and provided some verification of the literature predictions that CCST teachers would start with having students describe what they knew about a topic and then present an exposing event. Non-CCST teachers would be more likely to give an overview of the unit either generally or by giving specific behavioral objectives.

Part 2: Everyday Strategies - Section 2: Within A Unit

Within a unit, the steps in The Conceptual Change Strategy of Teaching for the teacher would be to have an exposing event to challenge the conceptual framework, to ask eliciting questions, to ask students to describe their thought processes, to have students state their hypotheses, to provide a free forum for debate or lab situations were students could test their hypotheses, and encourage elaboration. It would be predicted then that the CCST teachers would be significantly different on items [2], [8], [9], [12], and [14].

Item [9], *have students explain discrepant events*, was significantly different for the two groups (p=0.026) but only had a middle ranking (m1 = 7.0) for the CCST teachers. Item [12], *working in cooperative learning groups*, was the third most preferred method (m1 = 5.6) and was significantly different (p=0.004) for the CCST teachers than the non-CCST teachers. Item [14], *having students describing their thought processes*, was predicted to be more preferred by the CCST teachers and it was (p=0.000). However, the CCST teachers had a mean of only 7.9 which meant that even though they had ranked this item significantly more important than the non-CCST teachers, it was still not ranked very highly.

Item [2], *having students form and defend hypotheses*, was ranked in the middle by both groups (m1 = 7.4; m2 = 7.4) and was not significant (p=0.992). Item [8], *using simulations to have students predict outcomes*, was ranked in the middle (m1 = 7.2) but was not significant between the groups (p=0.791).

From the opposite standpoint, the CCST teachers, would not be expected to prefer the use of lecture or frequent assessment. Item [1], *lecture*, was the second least preferred method (m1 = 11.1) and item [6], *frequent assessment*, was the least preferred method (m1 = 11.6) and both were significantly different from the non-CCST group (p=0.000 and p=0.010 respectively).

Item [3], *having students perform lab experiments*, was the most preferred method of the CCST teachers (m1 = 3.6) but was not significant from the non-CCST teachers (p=0.077). Item [4], *doing demonstrations*, was the second most preferred method (m1 = 5.0) for the CCST teachers but was significant toward the non-CCST teachers (m2 = 3.5 and p=0.017).

Within a unit, the non-CCST teachers would be predicted to be significantly different in the use of lecture and they were. Item [1], *lecture*, was the third most preferred strategy for the non-CCST teachers (m2 = 6.1) and this was significantly different from the CCST teachers (p=0.000). This is not surprising since the literature review shows that this is the most commonly used method in the classroom with citations of 60% to 95%. The second most preferred strategy for the non-CCST teachers was item [4], *doing demonstrations*, with a mean of 3.5 and it was significant from the CCST teachers (p=0.017). This method is teacher-directed if the teacher just does demonstrations as a "show".

Items that had a medium ranking but were significantly different were [5], [6], and [7]. Item [5], *use of computer simulations*, and item [7], *use of technology to show everyday examples*, were not predicted as being significantly different methods for the two groups but they were found to be so (p=0.004; p=0.014). However, each method could still be used in a non-CCST way. Item [6], *frequent assessment*, was significantly different ($p=0.010$) as predicted but had a relatively low preference even with the non-CCST teachers ($m2 = 9.7$).

The most preferred method for the non-CCST teachers was item [3], *performing lab experiments*, ($m2 = 2.6$) but was not significantly different from the preference of the CCST teachers.

The conclusion at this point was that the two Groups, the CCST teachers and the non-CCST teachers, did show significant differences in what strategies they would use within a unit and provided some verification of the literature predictions that CCST teachers would have students explain discrepant events, describe their thought processes, and form and defend hypotheses. Although these strategies were found, the strategies were not always ranked in the top third of the preferred strategies to be used. It was found that the CCST teachers did not prefer the use of lecture or frequent assessment. The non-CCST teachers were found to prefer the use of lecture. They were also found to prefer the use of computer simulations and using technology to show examples but it is not known how these strategies were used.

Part 2: Everyday Strategies - Section 3: At the Conclusion of a Unit

The final step of The Conceptual Change Strategy of Teaching would be to have practical examples and new contexts in which students would test their hypotheses. Item [8], *a test with written, simulation, and practical parts*, was the most preferred method of assessment for the CCST teachers ($m1 = 2.3$) and was significantly different from the non-CCST teachers ($p=0.038$). For tests with new contexts, item [6], *a test with mixed format in new contexts*, was the second most preferred method for the CCST teachers and was significantly different from the non-CCST teachers (p=0.000). The other significant difference toward the CCST teachers was found on item [4], *an essay test in new contexts*, (p=0.000) but with a relatively low preference (m1 = 5.3).

From the counter standpoint, testing on the materials presented was not preferred by the CCST teachers with item [2], *an objective test on the material presented*, being the least preferred (m1 = 7.0) and significantly different (p=0.000) from the non-CCST teachers. The second least preferred method by the CCST teachers was item [1], *an essay test on the material presented*, (m1 = 6.5) but was not significantly different from the non-CCST teachers (p=0.459).

The non-CCST teachers were predicted to prefer item [2], *an objective test on the materials presented*, (p=0.000) more than the CCST teachers and they did. However, it still was not highly preferred (m2 = 4.9) . The most preferred by the non-CCST teachers was item [3], *a mixed format test on the material presented*, (m2 = 2.6). This not only was preferred but was also significantly different from the CCST teachers (p=0.002).

The conclusion at this point was that the two Groups, the CCST teachers and the non-CCST teachers, did show significant differences in how they would conclude a unit and provided some verification of the literature predictions that CCST teachers would have a more varied test that would cause students to need to explain what they knew about a topic and then would then have to apply their knowledge in new contexts. Non-CCST teachers would be more likely to give an objective test or a mixed format test but on the material as presented.

Part 3: Reason Behind Your Choices

The next part of the instrument was a series of statements that teachers had to rate on a scale of 1 to 5 with 5 being the most important as to their importance to the choices they made on Part 2: Everyday Strategies. In this part, m1 refers to the mean for the Group 1 teachers, labeled at this point as the CCST teachers (the Conceptual Change Strategy of Teaching teachers) and m2 refers to the mean for the Group 2 teachers, labeled at this point as the non-CCST teachers.

The CCST teachers were predicted to be significantly different on items [4], [7], [12], [14], and [16]. The non-CCST teachers, were predicted to be significantly different on items [9], [10], [13], and [15]. Items [17] and [18] were added as possible "why's" and were predicted to be significantly higher for Group 2. It was predicted that both Groups would be high on items [1], [2], and [3]. Items [5], [6], [8], and [11] had been placed on the instrument to see if any tentative conclusions could be drawn about pressures teachers felt in making their decisions. This was to tie in with Acjen's Theory of Reasoned Actions that choices are made based on an individual's beliefs and concern about how actions might be viewed.

Starting with the items that were predicted to be rated highly by both Groups, items [1], *motivational activities*, [2], *applications*, and [3], *exploring an idea to whet their appetites*, were rated highly by both Groups with all means 4.0 or higher for both Groups and no significant difference between the Groups. Items [1] and [3] are both attitudinal ones in that a student will probably learn more if interested first. This was referred to briefly in Chapter II but is not a focus of this study. Item [2] is an application question which refers back to the list of criteria for science literacy listed by Showwalter among others that includes an STS component.

The next set of items are the ones predicted to be significantly more important for the CCST teachers. Items [4], *interpreting ideas,* and [12], *forming and defending hypotheses,* were both rated as more important than by the CCST teachers with means of 4.6 and 4.2 respectively. Item [4] was significantly higher (p=0.000 as well as item [12] (p=0.002). Item [4] was also the most important item for the CCST teachers showing their concern for students interpreting their own ideas. However, even though statistically significantly lower, the mean for the non-CCST teachers of 4.2 does not look that much lower than the CCST teachers' mean of 4.6. So this item does not show much of a difference between the two groups even though statistically different. Item [14], *having students verbalize their thought processes*, is a key component of The Conceptual Change Strategy of Teaching. Although, it did turn out to be significantly different between the Groups (p=0.040), both Groups rated it highly. Item [16], *students testing their hypotheses in new situations,* was also significantly higher (m1 = 4.1; p=0.037) but both Groups ranked it highly. Item [7], *having a thought provoking demonstration and/or lab to stimulate explanations of phenomenon,* was rated highly by both Groups (m1 = 4.4 and mean 2 = 4.3) and showed no significant difference (p=0.509).

The next set of items are the ones predicted to be significantly more important for the non-CCST teachers. Item [9], *students needing to be focused first,* was rated with a medium rating for both Groups (m1 = 3.4 and m2 = 3.7) with no significant difference (p=0.307). Item [10], *students needing a strong framework and being told what they would be learning,* was significantly more important for the non-CCST teachers as expected (m2 = 3.9 and p=0.000). This is coupled with item [15], *students need to be told the facts several times*, that was also significantly higher (m2 = 2.3 and p=0.000). These both go along with part of the literature review and even more with informal interviews of some teachers who believe that a student must be told the facts "seven times" before they can learn them. Item [13], *students need help in discovering and organizing concepts*, was rated highly by both groups (m1 = 3.9 and m2 = 4.1) and showed no significant difference (p=0.311).

Items [17], *choices reflect how was taught*, and [18], *choices are presented by persons whose opinions are respected*, were added to see if the non-CCST teachers, would stand out and they did. In both cases, the non-CCST teachers rated [17] and [18] as more important but still at medium range. Item [17] was rated 2.8 (p=0.000) and item [18] was rated 3.4 (p=0.014).

Items [5], [6], [8], and [11] were rated higher by the non-CCST teachers, but only item [11] significantly. These dealt with making choices because of how they fit with [5], *the department* (m2 = 3.0), [6], *readings* (m2 = 3.5), [8], *principal* (m2 = 2.5), or [11], *parents* (m2 = 2.6).

The conclusion at this point was that the two Groups, the CCST teachers and the non-CCST teachers, did show significant differences in what reasons they found to be important in the choices they made in Part 2: Everyday Strategies and provided some verification of the literature predictions that CCST teachers would find it important to have students interpret ideas and form and defend hypotheses. The CCST teachers also found it important to have students test hypotheses in new situations. Although these reasons were found to be important to the CCST teachers, the reasons were not always rated as being that much important to the CCST teachers than to the non-CCST teachers. The non-CCST teachers were found to rate the use of a strong framework and telling the facts to students by the rule of "seven times" as more important than the CCST teachers did. Non-CCST teachers also found reasons such as outside opinions as being more important than the CCST teachers.

SUMMARY AND DISCUSSION

In beginning a unit, the preference for the use of behavioral objectives by the non-CCST teachers, is the method stressed by teacher preparation program and even more so by administrators. However, the CCST teachers preferred this method significantly less. The significant preference of the CCST teachers for having students describe what they know about a topic means that more emphasis is needed in this area.

Within a unit, the CCST teachers followed the steps of The Conceptual Change Strategy of Teaching except that item [14], *having students describe their thought-processes*, was ranked only in the middle. Personal interviews with teachers indicated that teachers find this a viable method but are not sure how to implement it. This would mean more training is needed in this area.

The conclusion of a unit, the evaluation or assessment, was significantly different between the two Groups. The CCST teachers showed a preference for testing with practical parts and testing in new contexts. This would seem to indicate a trend toward trying to test for higher order thinking skills and/or transference of the material learned. The non-CCST teachers showed more preference for tests on material covered.

Part Three, Reasons Behind Your Choices, showed results that were consistent with what was expected. The CCST teachers rated beliefs consistent with The Conceptual Change Strategy of Teaching. The non-CCST teachers also rated beliefs consistent with their framework.

Items [5], [6], [8], and [11] were rated higher by the non-CCST teachers, but only item [11] significantly. These dealt with making choices because of how the choices fit with [5], *the department* (m2 = 3.0), [6], *readings* (m2 = 3.5), [8], *principal* (m2 = 2.5), or [11], *parents* (m2 = 2.6). This is harder to explain but might indicate more "status quo" by the non-CCST teachers and more creativity by the CCST teachers. Since only item [11] is significantly higher (p=0.002), there is not much that can be concluded. However, they do show a trend of being higher. This might suggest a point made in one of the interviews that being more student-directed oriented takes a lot of courage and willingness to take some heat about choices.

The question then was "was Group 1 Conceptual Change Strategy of Teaching teachers"? Group 1 was significantly different in a number of areas but were they sufficient to label the teachers as Conceptual Change Strategy of Teaching teachers. In the section on Introduction to a Unit, item [7], *having students describe what they know about a topic*, would indicate that they were. Group 1's selection for At the Conclusion of a Unit also indicated a conceptual change orientation. However, the section on Within a Unit, was more difficult to interpret. The only item that was significantly different for Group 1 and ranked in the first third was item [12], *the use of cooperative learning groups.* It seemed as if the differences between the groups might be more based on learner-directed learning and teacher-directed learning.

What was the next step? If statistically it did not look like Conceptual Change Strategy of Teaching teachers had been found, would there be any help from the interviews? The first one considered was the written response from one of the reviewers. He stated that it had taken him 30 years to learn that being the "sage on the stage" was not the best way for his students to learn. He was now struggling with the best ways to get students to learn, work on higher thinking order skills, and problem solve. He is now out of the classroom and is the science and in-service coordinator for his school district. He is working on ways to involve the students more. He is one of the authors of the new chemistry text by Heath that stresses a problem solving approach.

From one of the in-person interviews, comments had arisen on this topic. This teacher was interviewed because he works very hard with his teaching strategies and has a Conceptual Change Strategy of Teaching trend. He commented that some of the Conceptual Change Strategies may have been chosen in Part 1 but not all the components in Part 2 because some teachers may have forgotten what some of the terms meant. He remembered what they meant but he was not sure everyone would. He also thought ranking 14 had been hard. However, this is defensible based on the advice from the consultants at the University of Cincinnati Institute on Policy Research. He also thought that it was very difficult for some teachers to give up "control" of their classes whether in reality, by habit, or at least admitting it on paper.

The conclusion at this point was that maybe teachers are beginning to move more toward learner-directed learning but are not sure what to do. In all three of the in-person interviews, the teachers expressed concern that they did not know how to do concept maps or vee-diagrams well with a group of students and did not know how to evaluate them. They expressed concern over how long it had taken them to do these diagrams when they had tried. Time pressures seemed to limit developing a new strategy or a way of using a strategy in a more timely fashion.

Concern was also expressed by all three that although they felt that teaching learning processes was important, the school community, especially the parents, did not value this process because that was not a skill directly assessed on major tests such as the SAT or ACT. Increasing parental pressures are changing what they feel they should teach to what they feel they have to teach.

AD HOC ANALYSES

Upon further reflection, it was decided that teachers' beliefs might be more indicative of their orientation than their choices on scenarios. Respondents were separated into Groups based on their ratings on Part 3. Items [4], *students need to interpret ideas for themselves,* [7], *students need to have a thought provoking ...to stimulate their explanation of phenomenon*, [12], *students need to form and defend their own hypotheses*, [14], *students need to verbalize their thought processes,* and [16], *students need to test their hypotheses in new situations* were placed on the instrument as beliefs indicative of Conceptual Change Strategy of Teaching teachers and [9], *students need to be focused on the topic first*, [10], *students need a strong framework to organize their learning and the need to be told what they will be learning,* [13], *students need help in discovering and organizing concepts*, and [15], *students learn best by being told the facts, being told them again, and being told again* were added as opposite beliefs. To place teachers in their new Groups, teachers who had rated the first group with 4's and 5's (but not all 4's) and had also rated the second set as 3 or lower were placed into new Group 1 and labeled the Believers. This was 23 teachers (31%). The other teachers were placed in new Group 2 and labeled the Non-believers. This was the remaining 51 teachers (69%). Analyses were run with these new Groups.

The data analyses were placed on the instrument. Analysis showed that most factors were statistically significant at an alpha level of 0.05.

Part 2: Everyday Strategies

The results of the ad hoc analysis are listed in Tables VIII - XI and listed in order of the instrument. mN1 refers to the means for the new Group 1, the Believers and mN2 refers to the means for the new Group 2, the Non-believers.

Table VIII. New Group Means for Introduction to a Unit.

mean	mN1	mN2	p	power at 0.05		
5.2	5. 8	4.9	0.083	0.40	[1]	... list of behavioral objectives before beginning
3.1	4.2	2.5	0.000	0.97	[2]	Give ... oral overview of what ... will be learning
5.9	5.9	6.0	0.862	0.04	[3]	... written pre-test of knowledge of a topic
5.1	5.9	4.7	0.004	0.81	[4]	Provide advanced organizers ...
1.9	1.7	2.0	0.316	0.13	[5]	Start with an attention-grabbing demonstration
4.2	3.0	4.8	0.000	0.95	[6]	Start the unit with a lab experiment
4.1	2.6	4.8	0.000	0.99	[7]	students describe what they know about a topic ...
6.5	6.9	6.4	0.172	0.21	[8]	Have students read and outline the chapter

Table IX. New Group Means for Within a Unit.

mean	mN1	mN2	p	power at 0.05		
8.3	12.2	6.4	0.000	0.99	[1]	Lecture using an overhead projector or chalkboard
7.4	6.0	8.0	0.038	0.53	[2]	Have students form and defend hypotheses
3.0	3.2	2.9	0.609	0.07	[3]	Have students perform lab experiments
4.3	4.9	4.0	0.177	0.26	[4]	Do demonstrations
9.4	10.1	9.0	0.212	0.23	[5]	Use computer simulations
10.5	12.3	9.6	0.001	0.90	[6]	Assess frequently such as with daily quizzes
7.6	8.9	7.0	0.037	0.53	[7]	Use ... technology to show everyday examples
7.4	7.5	7.4	0.933	0.03	[8]	Use simulations to ... predict outcomes
8.1	7.4	8.5	0.212	0.23	[9]	Have students explain discrepant events
7.2	4.7	8.5	0.000	0.96	[10]	... complete open-ended lab exercises
7.2	6.3	7.6	0.156	0.28	[11]	... small groups ... equal responsibilities
7.3	5.3	8.3	0.007	0.74	[12]	... cooperative learning groups ... roles... defined
7.3	8.0	7.0	0.257	0.20	[13]	... class discussions on topic and related issues
9.9	9.0	10.4	0.158	0.28	[14]	... students describing their thought processes ...

Table X. New Group Means for At the Conclusion of a Unit.

mean	mN1	mN2	p	power at 0.05	
6.3	7.0	6.0	0.001	0.73	[1] ... essay test on the material presented
5.9	7.2	5.3	0.000	0.94	[2] ... an objective test on the material presented
3.3	4.3	2.8	0.004	0.80	[3] ... a mixed format test on the material presented
6.0	5.2	6.3	0.002	0.84	[4] ... essay test on the material ... in new contexts
5.4	5.2	5.5	0.418	0.12	[5] ... objective test on the material ... in new contexts
3.1	2.7	3.4	0.052	0.36	[6] ... mixed format test on material ... in new contexts
3.1	2.6	3.3	0.031	0.44	[7] ... a test that has written and practical parts
2.9	1.8	3.3	0.000	0.78	[8] ... test ... written, simulation, and practical parts

Table XI. New Group Means for Reasons Behind Your Choices.

mean	mN1	mN2	p	power at 0.05	
4.5	4.7	4.4	0.091	0.38	1.) Students need motivational activities
4.5	4.6	4.5	0.436	0.12	2.) Students need applications in a lesson
4.1	4.3	4.0	0.088	0.39	3.) Students need to explore an idea to whet their appetites
4.4	4.9	4.0	0.000	1.00	4.) Students need to interpret ideas for themselves
2.8	2.6	2.9	0.223	0.22	5.) These choices fit with the requirements of my department
3.4	3.5	3.4	0.730	0.05	6.) These choices fit with ideas about which I have read
4.4	4.5	4.3	0.367	0.14	7.) Students need to have a thought provoking demonstration and /or lab to stimulate their explanation of phenomenon
2.2	2.0	2.3	0.420	0.12	8.) These choices fit the preferred lesson format of my principal
3.6	3.5	3.6	0.773	0.47	9.) Students need to be focused on the topic first.
3.4	2.4	3.9	0.000	1.00	10.) Students need a strong framework to organize their learning and they need to be told what they will be learning
2.3	1.9	2.5	0.051	0.48	11.) These choices reflect an approach parents like
3.9	4.4	3.6	0.000	0.96	12.) Students need to form and defend their own hypotheses
4.0	3.9	4.0	0.474	0.10	13.) Students need help in discovering and organizing concepts
4.2	4.3	4.2	0.242	0.21	14.) Students need to learn to verbalize their thought processes
2.0	1.3	2.2	0.000	0.92	15.) Students learn best by being told the facts, being told them again, and being told again.
3.9	4.5	3.7	0.000	0.97	16.) Students need to test their hypotheses in new situations
2.4	2.0	2.5	0.140	0.30	17.) These choices reflect the way in which I was taught
3.1	2.8	3.2	0.235	0.21	18.) These are effective choices because I have seen them presented by persons whose opinions I respect.

Part 2: Everyday Strategies -Section 1: Introduction to a Unit

Item [7], *having students describe what they know about a topic,* was the item ranked most preferred by the Believers (mN1 = 2.6) that was statistically different between the two new Groups (p=0.000). This ranking and significance was the same as for the original Group 1, the learner-directed teachers. However, in Section 2, Within a Unit, this method dropped in preferred ranking when compared to other methods (mN1 = 9.0) and was not significantly different.

The most preferred method of starting a unit for the Believers (mN1 = 1.7) was item [5], *start the unit with an attention-grabbing demonstration.* This was not significantly different from the other group (p=0.316). This does not add to the knowledge about the teachers in new Group 1, Believers, and how they may differ from the teachers in new Group 2, Non-believers, as the statement does not imply how the demonstration was used. Was the demonstration used strictly for attention or was it used to stimulate a discussion about why the demonstration proceeded as it did? Item [6], *start with a lab experiment,* was ranked with the third lowest mean (mN1 = 3.0) and was significantly different (p=0.000) from the other group.

From the opposite standpoint, these Believer teachers would not be expected to ask students to outline a chapter (mN1 = 6.9) or precondition students with [4], *advanced organizers* (mN1 = 5.9), [3], *a pre-test* (mN1 = 5.9), or [1], *behavioral objectives* (mN1 = 5.8).

For starting a unit, new Group 2, the Non-believers, would be expected to tell students what they would be learning. Item [2], *give an oral overview of the unit,* was also significantly more preferred by new Group 2 (p=0.000) and was their second most preferred method of starting a unit (mN2 = 2.5). The Non-believers also significantly preferred item [4], *advanced organizers* (p=0.004) from new Group 1 but it only had a mean of 4.7

The conclusion at this point was that the two new Groups did show significant differences in how they would start a unit. The Believers would start using a demonstration or by having students describe what they knew about a topic. The Non-believers would give students an oral overview of what they would be doing and provide advanced organizers.

Part 2: Everyday Strategies -Section 2: Within A Unit

Within a Unit, it would be predicted then that new Group 1, the Believers would be significantly different on items [2], [8], [9], [12], and [14]. Only [2] and [12] were significantly different.

Item [2], *having students form and defend hypotheses*, was ranked in the middle (mN1 = 6.0) and was significantly different between the two new Groups (p=0.038). Item [12], *working in cooperative learning groups*, was the fourth most preferred method (mN1 = 5.3) and was significantly different (p=0.007).

Item [8], *using simulations to have students predict outcomes*, was ranked in the middle (mN1 = 7.5) but was not significant form the other new group (p=0.933). Item [9], *have students explain discrepant events*, was also ranked in the middle (mN1 = 7.4) and was not significantly different for the two new groups (p=0.212).

Item [14], *having students describing their thought processes*, should have been significantly different for new Group 1, the Believers, because belief in this concept was one of the criterion used to separate the new Groups. However,it was not preferred (mN1 = 9.0) and was not significantly different (p=0.158).

From the opposite standpoint, the Believers would not be expected to prefer the use of lecture or frequent assessment. Item [1], *lecture*, was the second least preferred method (mN1 = 12.2) and item [6], *frequent assessment*, was the least preferred method (mN1 = 12.3) and both were significantly different from the other new group (p=0.000 and p=0.001 respectively).

Item [3], *having students perform lab experiments*, was the most preferred method of Group 1, the Believers (mN1 = 3.2) but was not significant from the other new group (p=0.609). Item [4], *doing demonstrations*, was the third most preferred method (mN1 = 4.9) but was not significant from the other new group (p=0.177).

Within a unit, new Group 2, the Non-believers, would be predicted to be significantly different in the use of lecture and it was. Item [1], *lecture*, was the third most preferred (mN2 = 6.4) and was significantly different from new Group 1, the Believers (p=0.000). The second most preferred method was item [4], *doing demonstrations*, with a mean of 4.0 but it was not significant from new Group 1, the Believers (p=0.177).

Items that had a medium ranking but were significantly different were [6], and [7]. Item [6], *frequent assessment*, was significantly different (p=0.001) as predicted but had a relatively low preference even with new Group 2 (mN2 = 9.6). Item [7], *use of technology to show everyday examples*, was preferred with a medium rank of 7.0 and was significantly different (p=0.037). The most preferred method was item [3], *performing lab experiments*, (mN2 = 2.9) but was not significantly different from new Group 1, the Believers.

The conclusion at this point was that the two new Groups did show significant differences in how they would teach within a unit. The Believers would have students form and defend hypotheses and use simulations to have students predict outcomes. The Non-believers would lecture and do demonstrations. They would also have students perform lab experiments.

Part 2: Everyday Strategies - Section 3: At the Conclusion of a Unit

Six of the eight methods of evaluation were found to be significantly different between the two new Groups. Item [8], *a test with written, simulation, and practical parts*, was the most preferred by the Believers (mN1 = 1.8) and was significantly different from the other new group (p=0.000). The second most preferred method for the Believers was item [7], *a test with written and practical parts* (mN1 = 2.6), and was significantly different (p=0.031). For tests with new contexts, item [6], *a test with mixed format in new contexts*, was the third most preferred method for the Believers (mN1 = 2.7) but was not significantly different from the Non-believers (p=0.052). The other significant difference toward the Believers was found on item [4], *an essay test in new contexts*, (p=0.000) but with a relatively low preference (mN1 = 5.2).

From the counter standpoint, testing on the materials presented was not preferred by the Believers with item [2], *an objective test on the material presented*, being the least preferred (m1 = 7.2) and significantly different (p=0.000) from the Non-believers. The second least preferred method by the Believers was item [1], *an essay test on the material presented,* (m1 = 7.0) but was significantly different from the Non-believers (p=0.001).

New Group 2, the Non-believers, were predicted to be lower on item [2], *an objective test on the materials presented*, (p=0.000) and they were. However, it still had a relatively high rank (m2 = 5.3) showing that it was not highly preferred. The most preferred item by the Non-believers was item [3], *a* *mixed format test on the material presented*, (m2 = 2.8). This not only had a low mean but was also significantly different from new Group 1 (p=0.004).

The conclusion at this point was that the two new Groups did show significant differences in how they would conclude a unit. The Believers would use almost any assessment method except objective tests on the material presented or an essay test on the material presented. The Non-believers would be most likely to use a mixed format test on the material presented.

Part 3: Reason Behind Your Choices

New Group 1, the Believers, were separated by rating items [4], [7], [12], [14], and [16] as important and rating items [9], [10], [13], and [15] as relatively unimportant. No other analyses were performed on this section since it was used as the basis for separating the new Groups.

Part 1: The Lesson Scenarios

How then did the two new Groups do on choosing the original lesson scenarios? Of the 23 teachers in new Group 1, the Believers, 18 had chosen at least two of The Conceptual Change Strategy of Teaching scenarios. Five had not. Of the 51 teachers in new Group 2, the Non-believers, 14 had chosen at least two of The Conceptual Change Strategy of Teaching scenarios and 37 had chosen less. This would indicate that the beliefs and the original lesson scenarios did not match into two groups. It seemed to indicate more categories were formed.

Conclusions from the Ad Hoc Analyses

This method really formed four categories of teachers. The first category is those who do not believe in The Conceptual Change Strategy of Teaching and do not use it. This was 37 of the teachers (50%). This category is easy to explain because if people do not believe in something, they probably will not do it. The second category is those who do believe in The Conceptual Change Strategy of Teaching and do use it. This was 18 of the teachers (24%). This category is also easy to explain because if people do believe in something, they will have a tendency to do it.

The third category is those who do believe in The Conceptual Change Strategy of Teaching but do not use it. This was 5 of the teachers (7%). Part 5 revealed some of the reasons they felt they could not use it with comments such as "student attendance", "no technology available", "size of classes", "no time to prepare any new lessons", "money", schedule disruptions", "standardized test results required", and "too tired".

The fourth category is those who do not believe in The Conceptual Change Strategy of Teaching but do use it. This was 14 of the teachers (19%). This category does not make sense when identified. Further analysis of their responses showed that the main criterion that set this category apart was how they rated beliefs in Part 3 which was how the new Groups were separated. Almost all of the teachers in this category showed little variance in their ratings on Part 3. Some circled "4" all the way down, some circled "3" most of the way, some gave all "4's" and "5's".

How then were these teachers to be more categorized as Non-believers or as doers? About this time, the last of the in-person interviews was held. This interview was held late because the teacher had been out of the country. He was asked why he thought teachers might have been in this category. He responded that he thought the belief part was the most difficult because he felt he was operating under two different sets of beliefs most of the time and that his department was going to have a retreat on this topic. The two belief sets were: (1) what he thought was best educationally and (2) what he believed he had to do in his school. He feels that students have to break many habits so it is hard to switch them to learner-directed lessons but he is trying to do so bit by bit. Testing in new contexts is ideal but parents routinely drop in at his school and ask to be showed step-by-step how grades were derived. He uses a combination of lecture and cooperative learning. Asked how he would separate himself as a teacher, he said about 60% process because he thinks that is important and 40% content based on his age, being from the "old school", and the school in which he teaches (private). Specifically on item [14] Within a Unit, *having students describe their thought processes*, he said he really did not know how to do that with students. Yet he knows that students at McMaster University have to do it all the time and are now the most sought after students in Canada.

This fourth category probably gives the most insight as to where help is needed. The current "Believers and Learner-directed teachers" and "Non-believers and Teacher-directed teachers" are probably set in their beliefs and thus, their methods. However, the category where teachers have conflicting beliefs is an area where help could be given. If the beliefs are what was found in the interview, that was is best educationally cannot necessarily be done in practicality, then help could be given in workshops or courses in how to implement The Conceptual Change Strategy of Teaching in a variety of situations and constraints.

GENERAL CONCLUSIONS ON THE PURPOSES

1. The Conceptual Change Strategy of Teaching is definable best in a chart form showing the steps that the teacher and the student must take. The unique step for this strategy is that the students must verbalize their thought processes along the way in a form in which the teacher can follow. It is also important for students to have the opportunity to test their hypotheses in new situations.

2. It is possible to design a survey instrument but it is a long process and is dependent on external input from a source such as the Institute for Policy Research.

3. Administering the instrument was greatly enhanced by using Dillman's The Total Design Method (Dillman, 1978).

GENERAL CONCLUSIONS FROM PARTS OF THE SURVEY

1. There are two types of teachers.

2. While some teachers use teacher-directed strategies, other teachers are using a variety of learner-directed strategies.

3. During the Introduction to a Unit, teachers are likely to be consistent with The Conceptual Change Strategy of Teaching by having students describe what they know about a topic. Yet Within a Unit, teachers do not see this

as the most important thing to do. Perhaps this is not knowing how to efficiently have students describe their thought processes and how to evaluate the processes.

4. The close ratings of the reasons behind the choices indicate a whole area to be explored that is beyond the scope of this study but upon which this study touched. That is, what is influencing a teacher? The very limited follow-up interviews would seem to indicate that teachers themselves do not know as they feel caught between what they feel they should do and what they feel they have to do for a number of reasons.

5. There was no apparent pattern in the profile of the teachers in the two groups and whether they were in the learner-directed group or the teacher-directed group.

6. There emerges a general feeling that there are a number of teachers who are working hard, despite limitations of time and money, despite the pressures of parents and school, to find better ways of insuring that their students are learning the best that they can and in ways that will help them in later life.

CONCLUSIONS ABOUT CCST TEACHERS

1.) In Introducing a Unit, there was a significant preference of the CCST teachers for having students describe what they know about a topic.

2.)Within a Unit, the CCST teachers followed the steps of The Conceptual Change Strategy of Teaching except that item [14], *having students describe their thought-processes* , was ranked only in the middle.

3.) Assessment was significantly different between the two Groups. The CCST teachers showed a preference for testing with practical parts and testing in new contexts. The non-CCST teachers showed more preference for tests on material covered.

4.)The CCST teachers rated beliefs consistent with The Conceptual Change Strategy of Teaching. The non-CCST teachers also rated beliefs consistent with their framework.

5.)The question then was “was Group 1 Conceptual Change Strategy of Teaching teachers”? Within a Unit seemed to indicate the differences between the groups might be more based on learner-directed learning and teacher-directed learning.

6.) Interviews - Maybe teachers are beginning to move more toward learner-directed learning but are not sure what to do.

OVERALL CONCLUSIONS

It would seem that there is a group of teachers in the Southwestern part of Ohio that believe in and are using learner-directed teaching and are working toward more of The Conceptual Change Strategy of Teaching. They are most likely to start a unit with an attention grabbing demonstration or a lab experiment and ask students to describe what they know about a topic. Within the unit, they will use cooperative learning and strategies designed to have students form hypotheses and work them through with lab or simulations. These teachers will test student learning using a mixed format of written and practical parts in new contexts. They have strong beliefs in what is and is not important and are willing to stand up to principals, parents, and department requirements to do what they think is important.

In returning to Showwalter's list as one example of the aspects that need to be considered in teaching scientific literacy, both Groups, learner-directed and teacher-directed teachers, showed a high interest in the Nature of Science and Skills by their high rankings of demonstrations and laboratory experiments. Bybee's emphasis on the implications of technology were seen throughout the instrument but were seen most clearly on Part 5, the comments section, as many teachers expressed the opinion that they could not teach the way they would choose because of too many restrictions on technology available.

Values and Interest were beyond what this study was to cover but the items [1] and [3] in Part 3 showed that these were each valued highly by both Groups. Science-Society was again rated highly by both groups whether in aspects of a lesson (part 2) with class discussions or simulations or the ratings in Part 3 on items [2] and [7].

Content and Processes are the last two areas on the list and the ones that probably stood out the most in the differences between the two groups in the study. Group 1, learner-directed teachers, seemed to be more interested in processes as evidenced by their ranking of elements within a lesson (Part 2) such as cooperative learning and lab experiments and their choices in Part 3 (reasons) mainly forming and defending hypotheses. Group 2, teacher-directed teachers, seemed more interested in content seen by their rankings in Part 2 but more so in their reasons in Part 3 rating items [10] and [15] significantly higher.

When considering the differences between Bruner and Gagne, there are elements on the survey that might indicate that this is the difference between the two Groups. Group 1, learner-directed teachers, ranked items such as outlining the chapter, pretesting, giving behavioral objectives, and advanced organizers as methods they probably would not use but mainly indicated starting with a demonstration. Within a lesson, they indicated more preferences toward lab, demonstrations, cooperative learning groups, and open-ended exercises, and the final test to be in new contexts. Although these are not step-by-step what discovery-learning would include, they do show an indication that way. On the other hand, Group 2, teacher-directed teachers, would be more likely to start by an overview of what was to come, lab and lecture, and an objective test on the materials presented because they indicated reasons of students needing a framework and needing to be told the facts several times showing more guided learning and more emphasis on the instructor.

Using Nussbaum and Novick's steps for facilitating accommodation, the first step is an exposing event. Both Groups ranked a demonstration as the most likely way to start a unit. Nussbaum and Novick's next step is to encourage students to describe their perceptions. This is where The

Conceptual Change Strategy of Teaching process seems to be breaking down. In the chemical education literature, some authors are trying to differentiate between a regular demonstration, lecture-demonstration, and problem-solving demonstrations. Informal interviews with teachers, discussion with two of the reviewers, and a formal interview with one of the participants all indicate this "feeling" that doing demonstrations is good but assessing what students learn from them is more important but most teachers are uncertain of how to do this.

This is where we are now. It was shown that teachers are not using The Conceptual Change Strategy of Teaching because they are leaving out the unique and critical factor of having students express their taught process in some form. The other Conceptual Change Strategy factors are there and in place with Group 1 teachers. Yet, with the interviews, and in the chemical education literature, there is a feeling that something else is needed beyond where most teachers are now. This study is the starting point for the next step toward identifying areas where teachers who believe in The Conceptual Change Strategy of Teaching and are trying to use it need help.

LIMITATIONS OF THE STUDY

This study was conducted to develop a definition of The Conceptual Change Strategy of Teaching, develop a checklist of its use, and then see if this strategy was being used in southwestern Ohio. Since the study is starting at this point, it may be used as the benchmark from which other studies may follow. At this point, the attempt was made to establish who is using The Conceptual Change Strategy of Teaching. The sample population were the high school teachers in the four counties of Hamilton, Butler, Clermont, and Warren in southwestern Ohio. Although the response rate was high (52.1%), it is recognized that this is a very small sample size from which to draw conclusions. Different types of schools were represented but there may still be unidentified characteristics of teachers in this area or in the respondents.

This study is also limited by not trying to find the explanation behind why some high school chemistry teachers are using The Conceptual Change Strategy of Teaching and some are not and if there are identifiable characteristics of high school chemistry teachers who are using The Conceptual Change Strategy of Teaching. This is being left for another study.

Literature reviews and early studies have shown The Conceptual Change Strategy of Teaching is being accepted as a viable method to use in the classroom. Later studies may attempt to see if The Conceptual Change Strategy of Teaching is a better method or just another alternative. The scope of the survey was the southwestern Ohio area. Other studies may survey larger populations.

IMPLICATIONS

Teachers themselves seem to be going through the steps of The Conceptual Change Strategy of Teaching. Many seem to be assessing their conceptions about how learners learn best. This seems to be influenced by many articles about different strategies and techniques such as cooperative learning, hands-on activities, and technology. Pressures are being felt from everywhere but especially from the Ohio State Department of Education as the new State Science Model is being developed. Some teachers seem to feel uncomfortable with the status quo in their schools.

What teachers need to hear is which strategies work from an educational standpoint and not a political viewpoint. Student testing has become a predominant factor in many schools with a number one priority among administrators. This leaves some teachers feeling that tests are driving the curriculum. Some teachers feel that "meeting a model" has become a process that must be accomplished but that the contents and decisions were made by politicians. Instead of starting with certain test results as the goal, teachers are interested in knowing what strategies help students learn better. The teachers would like to know which strategies have been tested and found to work.

The second step in The Conceptual Change Strategy of Teaching is to present an exposing event. This seems to be a favorite among all the high school chemistry teachers who responded since demonstrations were a very highly preferred strategy. However, a demonstration used as a thought-provoking exercise using higher order thinking skills is very difficult. This is one area where departments of chemistry could focus by presenting workshops highlighting this especially by some of the chemists especially known for this like Henry Bent, Dorothy Gabel, and Dudley Herron. In these workshops, a demonstration could be presented in several different ways showing how it could be used just for interest, how it could be used for verification of facts known, or how it could be used to cause students to have to problem-solve to find a way of explaining the observed phenomenon. Workshops could also be used to show demonstrations already adapted to the problem-solving mode. Help could be given in teaching a teacher how to adapt a demonstration and some of the questions that could be used to make the experience a problem-solving one for students.

The third step of The Conceptual Change Strategy of Teaching seems to be the one that teachers feel least comfortable in using. This was seen by the mixed ratings and rankings it received and the comments from the interviews. This step is when students are asked to describe their thought processes verbally or pictorially. This is where colleges of education can be of great help. Practical sessions need to be offered on efficient ways of using this technique in the classroom and advice given for evaluating the processes.

The three teachers interviewed said they did not know how to teach students to make concept maps. They had all tried and found it to be a frustrating and very time-consuming exercise. Even when it was over, they said they could not tell if students had learned and did not know how to assess what students had learned. These teachers are all ones that have been taking classes lately and ones that work very hard on how their students learn in addition to what they learn. Even as exceptional teachers, they were finding the process of following a student's thinking process difficult. The steps learned in doing a detailed protocol analysis are usually taught in an education course but from the perspective of how to do it one-on-one in an interview and debriefing process. What teachers want to know is how to do it with a class, especially if the class has thirty-five or forty students.

Step four of The Conceptual Change Strategy of Teaching is a mixed one for teachers. Providing a free forum and a chance for discussion are ones the teacher can do. Providing the right kind of lab experiments may be more difficult. This is a case where the departments of chemistry and colleges of education need to work together to be sure that both the chemistry and educational components are there to push the students into making higher order hypotheses.

Most laboratory experiments are written from a verification standpoint. Many tell the students what to look for. To students, the lab experience becomes one of rotely following the steps and finding the answers they were told to find. The experiments need to be ones that have students trying to emulate scientists as much as possible in trying to use the scientific method to discover the steps needed and ones where the results are not always expected. Students need to work through what they have seen and find explanations that fit the phenomenon. Chemists need to help to devise experiments that are safely and easily performed and ones that have unique results. Members of the colleges of education need to help to input meeting higher order thinking skills and devising questions that push students to think in order to answer them.

This collaboration is also needed to help with step five of The Conceptual Change Strategy of Teaching where new, practically oriented situations in everyday context are presented. Since most teachers already feel pressured by time constraints, they have little time for developing new ideas and so they will need input. Some teachers put on their survey instruments comments that they would like to add more components to their lessons but that they either had no time to devise new ones or were too tired at the end of the day to feel like devising new ideas. Even in the literature review, authors said that new, practically oriented situations that fit students' everyday context are difficult to devise but they offered no comments on how to devise these or any examples. Since this is a key step to The Conceptual Change Strategy of Teaching, where students will test their actual learning of the material by testing it in new contexts, it cannot be eliminated. Teachers are looking to experts in the field to devise the situations or at least develop a quick and easy way for them to be devised. Members of colleges of education and departments of chemistry could work in collaboration developing some situations that teachers could use. If the lessons involved media or technology, these would have to be of a professional quality for teachers to want to use them and for students to respond to them. Having teachers in so many different settings whether by grade level taught, subject matter, topics within a course, or by backgrounds of the students would mean that large number of situations would need to be devised.

What can be proposed for further study? One of the starting premises for this study was that The Conceptual Change Strategy of Teaching was but one method that a teacher could use. Further study could explore whether this is a better method for teachers to use or just a different method to use.

Another question is to discover more about the teachers who are the learner-directed teachers and see what characteristics make them different from other teachers. Is it their belief system or are their other factors? If it is their belief system, are there ways this belief system can be altered? If it is other factors, what are they and can they be altered?

If some teachers' perspective of state politicians running the school systems and the curriculum is true, further study could explore whether or not there are identifiable differences between use of The Conceptual Change Strategy of Teaching use from one state to another. This could lead to several different related studies such as the effects of different types of state models, the effects of school administration from the extremes of Maryland with only eight school districts to states like Ohio with over 600, and the effects of school financing.

One study that many teachers want to know about, for any change, is how do students perform in the future. One study could be to track students who have had a basically teacher-directed background and students who have had a learner-directed and/or conceptual change background through college and see if there are differences in performance in college and jobs received after graduation.

Perhaps the most useful follow-up study for proponents of The Conceptual Change Strategy of Teaching would be to develop the steps discussed earlier in this section. This would be communicating with teachers about strategies that do work and ways of implementing them in the classroom. It would be providing workshops that teach teachers how to provide thought-provoking demonstrations. Workshops would also need to be provided to show teachers how to have students describe their thought processes in ways that will work in crowded classrooms. Situations would have to be developed that would allow students to test their hypotheses in new, practically oriented situations in everyday context.

This study is just the beginning of describing how the theory of conceptual change can be translated into use in the classroom. Some teachers believe in this method and are attempting to use it. The goal of The Conceptual Change Strategy of Teaching, as with most strategies, is to have students truly learn and in a way that will most benefit them in the years to come.

REFERENCES

Abraham, M. R. (1982). Sequencing Language and Activities in High School Chemistry. ERIC #ED 2441267.

Alyea, H. (1985). Lecture presented at Princeton University, July 17, 1985.

American Association for the Advancement of Science (1989). Project 2061: Science for All Americans. Washington, D.C.: American Association for the Advancement of Science, Inc.

American Chemical Society (1987). Recommendations for the Education of Chemistry Teachers. Washington, DC: American Chemical Society.

American Chemical Society (1984). Tomorrow: The Report of the Task Force of Chemical Education in the United States. Washington, DC: American Chemical Society.

American Chemical Society (1984). Guidelines and Recommendations for the Teaching of High School Chemistry. Washington, DC: American Chemical Society.

American Chemical Society (1977). Guidelines and Recommendations for the Teaching of High School Chemistry. Washington, DC: American Chemical Society.

Anderson, C. W. (1987). Incorporating Recent Research on Learning into the Process of Science Curriculum Development. Boulder, CO: The Biological Curriculum Study.

Anderson, C. W. and Smith, E. L. (1987). Teaching Science. In Richardson-Koehler (ed.). Educators' Handbook : A Research Perspective. New York, NY: Longman.

Anderson, R. D. (1983). A Consolidation and Appraisal of Science Education Meta-Analysis. Journal of Research in Science Teaching, 20(5), 497-509.

Anderson, R. D. (1981). Physical Science Education. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Ajzen, I. and Fishbein, M. (1980). Understanding Attitudes and Predicting Social Behavior. Engelwood Cliffs, NJ: Prentice-Hall, Inc.

Ausbel, D. P. (1968). Educational Psychology: A CognitiveView. New York, NY: Holt, Rinehart, and Winston.

Ausubel, D. P., Noavk, J. D., and Hanesian, H. (1978). Educational Psychology: A Cognitive View (2nd ed). New York, NY: Holt, Rinehart, and Winston.

Barman, C. R. and Kotar, M. (1989). The Learning Cycle. Science and Children, April, 1989.

Basili, P. A. and Sanford, J. P. (1991). Conceptual Change Strategies and Cooperative Group Work in Chemistry. Journal of Research in Science Teaching, 28(4), 293-304.

Bates, G. C. (1978). The Role of the Laboratory in Secondary Science Education. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Bell, Jerry(1985). Lecture given at Princeton University, July 24, 1985.

Bent, H. (1988). Lecture given at the American Chemical Society Cincinnati Section Workshop, March 12, 1988.

Bent, H. (1985). Lecture given at Princeton University, Juy 3, 1985.

Blosser, P. E. (1989). A paper presented at the Science Education Council of Ohio Annual Meeting, February 10, 1989.

Blosser, P. E. (1981). A Critical Review of the Role of the Laboratory in Science Teaching. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Bobbie, E. (1990). Survey Research Methods. 2nd ed. Belmont, CA: Wadsworth Publishing Co.

Bodner, G. D. (1990). Paper presented at the Bienneniel Conference on Chemical Education, August 6, 1990.

Bodner, G. D. (1989). Lecture given at a monthly American Chemical Society Meeting, Cincinnati Section, October 11, 1989.

Bonnstetter, R. J., Penick, J. E., and Yager, R. E. (eds.) (1983). Teachers in Exemplary Programs: How Do They Compare? Washington, DC: NSTA Publications.

Bradley, J. D. and Brand, M. (1985). Stamping Out Misconceptions. Journal of Chemcial Education, 62, 318.

Brandt, R. (1992). On Research on Teaching. Educational Leadership, 49, (7), 14-19.

Brophy, J. (1992). Probing the Subtleties of Subject Matter Teaching. Educational Leadership, 49, (7), 4-8.

Bruner, J. S. (1961). The Process of Education. Cambridge, MA: Harvard University Press.

Carrozza, Mark A. and Smith, Andrew E. Personal conversations, April 5, 6, 8, 12, and 21, 1993.

Champagne, R. F. and Klopfer, L. E. (1981). Structuring Process Skills and the Solution of Verbal Problems Involving Science Concepts. Science Education, 65(5), 493-511.

Champagne, R. F., Klopfer, L. E. and Gunstone, R. F. (1982). Cognitive Research and the Design of Science Instruction. Educational Psychology, 17(1), 31-53.

Chance, P. (1986). Thinking in the Classroom: A Survey of Programs. New York, NY: Teachers College Press.

Chiappetta, E. L. (1976). A Review of the Piagetian Studies Relevant to Science Instruction at the Secondary and College Level. Science Education, 60(2), 253-261.

Clarizo, H. F., Craig, R. C., and Mehrens, W.A. (eds.) (1974). Contemporary Issues in Educational Psychology. Boston, MA: Allyn and Bacon, Inc.

Costa, A. L. (ed.) (1985). Developing Minds: A Resource Book for Teaching Thinking. Alexandria, VA: Association for Supervision and Curriculum Development.

DeRose, J. V., Lockard, J.D. and Paldy, L. G. (1979) The Teacher is the Key: A Report on Three NSF Studies. In Status of Pre-College Science, Mathematics, and Social Science Education: 1955-75. Columbus, OH: The Center for Science and Mathematics Education.

Dillashaw, F. G. and Okey, J. R. (1981) The Effects of a Modified Mastery Learning Strategy on Achievement, Attitudes, and On-Task Behavior of High School Chemistry Students. ERIC # ED 210 515

DiSessa, A. A. (1982). Unlearning Aristotelian Physics: A Study of Knowledge-Based Learning. Cognitive Science, 6, 37-75.

Driver, R. and Easley, J. (1978). Pupils and Paradigms: A Review of Literature Related to Concept Development in Adolescent Science Students. Studies in Science Education, 5, 61-84

Druva, C. A. and Anderson, R. D. (1983). Science Teacher Characteristics by Teacher Behavior and Student Outcomes: A meta-analysis of Research. Journal of Research in Science Teachng, 20(5), 467-480.

Eggen, P., Kauchak, D., and Harder, R. (1979). Strategies for Techers Information Processing Models in the Classroom. Englewood Cliffs, NJ: Prentice-Hall Inc.

Elfner, L. E. (1990). Speech given at The Ohio Academy of Science Junior Academy of Science Meeting, April 27, 1990.

Fensham, P. J. (1983). A Research Base for New Objectives of Science Teaching. Science Education, 67(1), 3-12.

Festinger, L. (1957). A Theory of Cognitive Dissonance. Evanston, IL: Rwo and Peterson Publishers.

Festinger, L. (1954). A Theory of Social Comparison Processes. Human Relations, 7, 117-140.

Festinger, L. (1950). Informal Social Communication. Psy. Review, 57,271-282.

Fowler, T. W. (1984). Lecture presented at the University of Cincinnati, October 9, 1984.

Gabel, D. (1986). Paper presented at the Science Education Council of Ohio Convention, February 14, 1986.

Gabel, D. (1985). Paper presented at the National Science Teachers Association National Convention, October 25, 1985.

Gabel, D. and Sherwood, R. (1986). High School Students' Ability to Solve Molarity Problems and Their Analog Counterparts. Journal of Research in Science Teaching, 23(2), 165-176.

Gabel, D. and Sherwood, R. (1984). Analyzing Difficulties with Mole-Concept Tasks by Using Analog Tasks. Journal of Research in Science Teaching, 21(8), 843-851.

Gabel, D., Sherwood, R., and Enochs, L. (1984). Problem-solving Skills of High School Chemistry Students. Journal of Research in Science Teaching, 21(1), 221-233.

Gallup, G. H. (1984). The 16th Annual Gallup Poll of the Public's Attitudes Toward the Public Schools. Phi Delta Kappan, , 1 -16.

Gardner, M. H. (1988). New Trends in Chemical Education and Chemistry Teacher Education Worldwide. Chemical Society Review, 17, 135-146.

Gersten, R., Woodward, J., and Marvant, M. (1992). Refining the Working Knowledge of Experienced Teachers. Educational Leadership, 49, (7), 34-39.

Gideonse, H. D. (1985). Lecture given at the University of Cincinnati, May 16, 1985.

Gilbert, J. K., Osbourne, R. J. and Fensham, P. J. (1982). Children's Science and Its Consequences for Teaching. Science Education, 66(4), 623-633.

Good, R. (1984). Scientific Problem-solving by Expert Systems. Journal of Research in Science Teaching, 21(3), 331-340.

Granville, M. (1985). Student Misconceptions in Thermodynamics. Journal of Chemical Education, 62, 847-848.

Hashweh, M. (1988). Descriptive Studies of Students' Conceptions in Science. Journal of Research in Science Teaching, 22(2), 121-134.

Hashweh, M. Z. (1986). Toward an Explanation of Conceptual Change. European Journal of Science Education, 8(3), 229-249.

Helgeson, S. L., Blosser, P. E., and Howe, R. W. The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-75. Columbus, OH: The Center for Science and Mathematics Education.

Helm, H., and Novak, J. D. (1983). Misconceptions in Science and Mathematics. Ithaca, NY, Cornell University Press.

Helm, H. and Novak, J. D. (1982). Misconceptions in Science and Mathematics. ERIC # ED 242 553

Herron, J. D. (1983). What Can Educators Teach Chemists About Teaching Chemistry? Journal of Chemical Education, 60(11), 47.

Hewson, P. W. (1981). A Conceptual Change Approach to Learning Science. European Journal of Science Education, 3, (40), 383-396.

Hewson, M. G. and Hewson, P. W. (1983). Effect of Instruction Using Students' Prior Knowledge and Conceptual Change Strategies on Science Learning. Journal of Research in Science Teaching, 20(8), 731-743.

Holdszkom, D. and Lutz, P. B. (1986). Research Within Reach: Science Education: A Research-Guided Response to the Concerns of Educators. Columbus, OH: Ohio Department of Education.

Horton, P. B. (1981). The Role of Teacher Characteristics and Personality in Student Learning in Individualized Science Programs. ERIC # ED 211 381.

Hunter, R. (1988). A lecture given at a Hamilton County Workshop, June 15, 1988.

Hurd, P. D. (1993). Paper presented at the regional National Science Teachers Association Convention, Novermber 12, 1993.

Hurd, P. D. (1985). Action for Excellence in Science Education: Update on the National Commission Reports. Science Education in Ohio, 3(1), 1-10.

Hurd, P. D. (1984). Paper presented at the Ohio Department of Education Science Staff Development Conference, October 11, 1984.

Hurd, P. D. (1982). Biology Education. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Hurd, P. D. (1971). Research in Science Education: Planning for the Future. Journal of Research in Science Teaching, 8(3), 243-249.

Jones, B. F., Palincsar, A. S., Ogle, D. S., and Carr, E. G. (1987). Strategic Teaching and Learning: Cognitive Instruction in the Content Areas. Alexandria, VA: Association for Supervision and Curriculum Development.

Joyce, B. and Weil, M. (1972). Models of Teaching. Engelwood Cliffs, NJ: Prentice-Hall, Inc.

Kahle, J. B. (1986). Encouraging Girls in Science Courses and Careers. In Research Matters... To the Science Teacher. Washington, DC: NSTA Publications.

Karpus, R, and Lawson, C. A. (1974). SCIS Teacher's Handbook. Berkeley, CA: Science Curriculum Improvement Study.

Kyle, W. C. (1980). The Distinction Between Inquiry and Scientific Inquiry and Why High School Students Should Be Cognizant of the Distinction. Journal of Research in Science Teaching, 17(2), 123-130

Kyle, W. C., Penick, J. E., and Shymansky, J. A. (1980). Assessing and Analyzing Behavior Strategies of Instructors in College Science Laboratories. Journal of Research in Science Teaching, 17(2), 131-137.

Ladd, G. T. and Anderson, H.O. (1970). Determining the Level of Inquiry in Teachers' Questions. Journal of Research in Science Teaching, 7(4), 395-400.

Larkin, J. (1980). Teaching Problem-solving in Physics: The Psychological Laboratory and the Practical Classroom. In D.Tuma and F. Reif (eds.), Problem Solving and Education: Issues for Teaching and Research (pp. 111-125). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Larkin, J. and Rainhard, B. (1984). A Research Methodology for Studying How People Think. Journal of Research in Science Teaching, 21(3), 235-254.

Lawrenz, F. (1975) The Relationship between Science Teacher Characteristics and Student Achievement and Attitude. Journal of Research in Science Teaching, 12(4), 433-437.

Lawson, A. E. (ed.) (1980). The Psychology of Teaching for Thinking and Creativity, Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Lawson, A. E. (1979). The Developmental Learning Paradigm. Journal of Research in Science Teaching, 16(6), 501-515.

Lawson, A. E. and Renner, J. (1975). Relationships of Science Subject Matter and Development Levels of Learners. Journal of Research in Science Teaching, 12, 347-358.

Leinhardt, G. (1992). What Research on Learning Tells Us About Teaching, Educational Leadership, 49, (7), 20-25.

Markle, G. C. (1990). Why U.S. High School Graduates Lack Scientific Literacy. Paper presented at the Annual Meeting of The National Science Teachers Association, April 6, 1990.

Marzano, R. J., Brandt, R. S., Hughes, C. S., Jones, B. F., Presseisen, B. Z., Rankin, S. C., and Suhor, C. (1988). Dimensions of Thinking: A Framework for Curriculum and Instruction. Alexandria, VA: Association for Supervision and Curriculum Development.

Mayer, R. E. (1983). Thinking, Problem Solving, Cognition. New York, NY: W. H. Freeman and Company.

Minor, K. (1984). A paper presented at the Ohio Department of Education Science Staff Development Conference, October 11, 1984.

Moore, R. W. and Sutman, F. X. (1970). The Development, Field Test, and Validation of an Inventory of Scientific Attitudes. Journal of Research in Science Teaching, 7 (2), 85-94.

Munby, H. (1983). An Investigation into the Measurement of Attitudes in Science Education. Columbus, OH: SMEAC Information Reference Center.

National Commission on Excellence in Education (1983). A Nation at Risk: The Imperative for Educational Reform. Washington, DC: U.S. Department of Education.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology (1982). Educating America for the 21st Century. Washington, DC: National Science Foundation.

National Science Teachers Association (1982). An NSTA Position Statement. Washington, DC: NSTA Publications.

Newell, A. and Simon, H. (1972). Human Problem-Solving. Englewood Cliffs, NJ: Prentice-Hall.

Novak, J. (1978). An Alternative to Piagetian Psychology for Science and Mathematics Education. Science Education, 5, 1-30.

Novak, J., Gowin, D., and Johansen, B. (1983). The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Students. Science Education, 67(5), 625-645.

Novick, S. and Nussbaum, J. (1978). Junior High School Pupils' Understanding of the Particulate Nature of Matter: An Interview Study. Science Education, 62(3), 273-281.

Nussbaum, J. (1979). Children's Conceptions of the Earth as a Cosmic Body. Science Education, 63(1), 83-93.

Nussbaum, J. and Novick, S. (1982). Alternative Frameworks, Conceptual Conflict and Accommodation: Toward a Principled Teaching Strategy. Instructional Science, 11, 183-200.

Onoske, J. I. (1992). Exploring the Thinking of Thoughtful Teachers. Educational Leadership, 49, (7), 40-43.

Osborne, R. J. and Wittrock, M. C. (1983). Learning Science: A Generative Process. Science Education, 67(4), 489-508.

Penick, J. E. and Krajcik, J. (eds.) (1984). Focus on Excellence: Chemistry. Washington, DC: NSTA Publications.

Perkins, R. (1986). Paper presented at the American Chemical Society Cincinnati Section Workshop, March 15, 1986.

Possner, G. J. and Gertzog, W. A. (1982). The Clinical Interview and the Measurement of Conceptual Change. Science Education, 66(2), 195-209.

Possner, G. J., Strike, K. A., Hewson, P. W., Gertzog, W. A. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. Science Education, 66(2), 211-227.

Prawat, R. S. (1992). From Individual Differences to Learning Communities - Our Changing Focus. Educational Leadership, 49, (7), 9-13.

Rammette, R. (1985). Lecture presented at Princeton University, July 23, 1985.

Raven, R. J. and Adrian, M. (1978). Relationships Among Science Achievement, Self-Concept, and Piaget's Operative Comprehension. Science Education, 62(4), 471-479.

Raven, R. J. and Murray, R. B. (1978). Effect of High School Chemistry Experiences on Piaget's Operative Comprehension. Science Education, 62(4), 467-470.

Renner, J. W. (1976). The Learning Cycle and Secondary School Science. Norman, OK: University of Oklahoma Press.

Resnick, L. B. (1987). Education and Learning to Think. Washington, DC: National Academy Press.

Resnick, L. B. and Klopfer, L. E. (eds.) Toward the Thinking Curriculum: Current Cognitive Research. Alexandria, VA: Association for Supervision and Curriculum Development.

Rief, F. (1983). How Can Chemists Teach Problem-solving? Journal of Chemical Education, 60(11), 948-953.

Roadruck, M. (1985). Lecture presented at Princeton University, July 18. 1985.

Rosenshine, B. and Meister, C. (1992). The Use of Scaffolds for Teaching Higher Level Cognitive Strategies. Educational Leadership, 49, (7), 26-33.

Rossi, P. H., Wright, J. D., and Anderson, A. B. (1983). Handbook of Survey Research. Orlando, FL: Academic Press, Inc.

Rothman, A. I. (1969). Teacher Characteristics and Student Learning. Journal of Research in Science Teaching, 6(1), 59-63.

Rowe, M. B. (ed.) (1978) What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Rowell, J. A. and Dawson, C. J. (1983). Laboratory Counterexamples and the Growth of Understanding in Science. European Journal of Science Education, 5(2), 203-215.

Rubba, P. A. and Anderson, H. O. (1978). Development of an Instrument to Assess Secondary School Students' Understanding of the Nature of Scientific Knowledge. Science Education, 62(4), 449-458.

Ryans, D. (1960). Characteristics of Teachers. Washignton, DC: American Council of Education.

Sarquis, A. M. (1988). Lecture presented at Miami University-Middletown, September 17, 1988.

Showwalter, W. (1984). Paper presented at the Ohio Department of Education Science Staff Development Conference, October 11, 1984.

Shrigley, R. L. (1983). The Attitude Concept and Science Teaching. Science Education, 67(4), 425-442

Shulman, L. S. (1968). Psychological Controversies in the Teaching of Science and Mathematics. Science Teacher, 35, 34-38, 89-90.

Shulman, L.S. and Keislar, E. R. (1966). Learning by Discovery: A Critical Appraisal. ERIC # Ed 015 504.

Shymansky, J. (1987). Paper presented at the Ohio Department of Education Science Staff Development Conference, October 10, 1987.

Shymansky, J. (1985). A paper presented at the National Science Teachers Association National Convention, October 25, 1985.

Shymansky, J. (1984). A paper presented at the Ohio Department of Education Science Staff Development Conference, October 13, 1984.

Shymansky, J. (1978). How Teaching Strategies Affect Students: Implications for Teachng Science. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Shymansky, J., Penick, J., Mathews, C., and Good, R. (1977). A Study of Students Classroom Behavior as it Relates to Problem-solving. Journal of Research in Science Teaching, 14(3), 191-198.

Simpson, R. D. (1979). Breeding Success in Science. The Science Teacher, 46(11), 24-26.

Simpson, R. D. (1978). Relating Student Feelings to Achievement in Science. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Stake, R. E. and Easley, J. (1978). Case Studies in Science Education. ERIC # ED 166 058

Stavy, R. (1991). Using Analogy to Overcome Misconceptions About Conservation of Matter. Journal of Research in Science Teaching, 28(4), 305-313.

Stewart, J. (1982). Two Aspects of Meaningful Problem-solving in Science. Science Education, 66(5), 731-749.

Stofflett, R. T. (1992). Is the Ability to Use Conceptual Change Pedagogy a Function of Personal Experience? A paper presented at the National Association of Research in Science Teaching.

Sweitzer, G. L., Howe, R. W., Helgeson, S. L., and Blosser, P.E. (1982). A Meta-Analysis of Research on Science Teacher Education Practices Associated with Inquiry Strategy. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Sykes, G. (1984). Teaching in America: The Deal.The Wilson Quarterly, VIII(1), 59-77

Tuma, D. T. and Reif, F. (ed.) (1980). Problem Solving and Education: Issues in Teaching and Research. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Vosniadou, S. and Brewer, W. F. (1987). Theories of Knowledge Restructuring in Development. Review of Educational Research, 57(1), 51-67.

Waddling, R. (1983). Titration Calculations: A Problem-solving Approach. Journal of Chemcial Education. 60(3), 230-232.

Wallen, N. E. and Fraenkel, J. P. (1991). Educational Research: A Guide to the Process. New York, NY: McGraw-Hill, Inc.

Walters, F. B. et. al. (1988). New Dimensions in Science. Columbus, OH: Ohio Department of Education.

Watson, B. and Konicek, R. (1990). Teaching for Conceptual Change: Confronting Children's Experience. Phi Delta Kappan, May, 1990.

Welch, W. W. (1981). Inquiry in Science Education. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Welch, W. W. and Lawrenze, F. (1982). Characteristics of Male and Female Teachers. Journal of Research in Science Teaching, 19(7), 587-594.

Welch, W. W. and Pella, M. (1963). The Development of an Instrument for Inventorying Knowledge of the Processes of Science. Journal of Research in Science Teaching, 1(1), 64-68

Wheeler, A. E. and Kass, H. (1978). Student Misconceptions in Chemical Equilibrium. Science Education, 62(2), 223-232.

Whimbey, A. and Lochhead, J. (1986). Problem Solving and Comprehension. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Wise, K. C. and Okey, J. R. (1985). Teaching Strategies: Are Some Ways of Teaching Science Better that Others? Paper presented at the National Science Teachers Association National Convention, October 25, 1985.

Yager, R. E. (1991). The Constructivist Learning Model: Toward Real Reform in Science Education. The Science Teacher, September, 1991.

Yager, R. E. (1985). Lecture presented for the Hamilton County In-Service Workshop, October 25, 1985.

Yager, R. E. (1984). Paper presented at the Ohio Department of Education Science Staff Development Conference, October 11, 1984.

Yager, R. E. (1983). Exemplary Program in Physics, Chemistry, Biology and Earth Science. Washington, DC: NSTA Publications.

Yager, R. E. (1982). What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Yager, R. E. (1981). Prologue. In What Research Says to the Science Teacher. Washington, DC: NSTA Publications.

Yager. R. E. and Penick, J. (eds.) (1985). Focus on Excellence: Science in Non-School Settings. Washington, DC: NSTA Publications.

Yeaney, R. H. (1991). A Unifying Theme in Science Education? NARST News, 33(2), 1-3.

Yinger, R. (1984). A lecture presented at the University of Cincinnati, April 19, 1984.

APPENDIX A

THE INSTRUMENT

A SELF-REPORTING SURVEY INSTRUMENT OF HIGH SCHOOL CHEMISTRY TEACHERS AND THEIR TEACHING STRATEGIES

PART 1: LESSON SCENARIOS

In this part, there are three different topics typically covered in a general high school chemistry class. For each of these topics, two different scenarios are given as possible ways of introducing the topic. For each lesson, please read the scenarios and place a check in the box of the scenario within each topic you would **more likely** use in your classroom if you had no restrictions due to money, equipment, supplies, time, facilities, or administration.

LESSON 1: PERIODIC TABLE

SCENARIO 1: This unit would be started showing the ChemStudy film Chemical Families. This would be followed by a discussion of the film and a description of the unit and what students would need to know. The **second** day students would do a lab experiment on one of the chemical families such as the halogens to see the trends in the family. On the **third** day, there would be a lecture for part of the period outlining the historical development of the Periodic Table and how it would be used to predict characteristic properties of the known elements. Students would then have a chance to cut straw with the lengths representing the ionization energies and mount the straws. Using these straw heights, students would draw the arrows for the periodic trend of this property. The **fourth** day would include an assessment (quiz) of the knowledge learned to date including predicting the ionization energy for element 113.

SCENARIO 2: This unit would be started with students in groups being asked to form a Periodic Table with elements from another planet given a few of the chemical and physical properties of the elements. Each group would then explain their Periodic Tables to the class. Next, groups would be given copies of Mendeleyev's original Periodic Table and asked to decide how the current Periodic Tables is different and how these changes might have occurred. The **second** day students would do a lab experiment on the Period 3 elements. On the **third** day, students would be asked to compare and contrast properties found in lab within their groups and using a poster show the group's results. They would then be shown slides of some elements (without their names) and asked to predict to which family they would belong and why. The **fourth** day would include an assessment (quiz) of the concepts learned to date using new elements.

Which scenario for the Periodic Table lesson would you choose?

[__] Scenario 1

[__] Scenario 2

LESSON 2: GAS LAWS

SCENARIO 1: In the unit on gas laws, students would be asked to list examples in their everyday lives that include gases and asked to generalize (using words or pictures) about behaviors of gases. Students would be shown a demonstration of the collapsing can and asked to describe why the change is occurring using their generalizations The students would then be asked to write a scheme for quantitatively predicting a similar occurrence. The **second** day would be a lab experiment on determination of molar masses using aqueous ammonia and hydrochloric acid. On the **third** day, students would then be asked to share their results and discuss how they found their conclusions and how this could be used to describe and predict reactions in industry. The **fourth** day would include an assessment (quiz) of the concepts learned to date using a simulation.

SCENARIO 2: In the unit on gas laws, students would first see a series of demonstrations such as collapsing cans, Boyle's Law, Charles' Law, flow of gases through a porous cup, and others. The **second** day students would be given the gas laws, practice some examples of problems together in class, and then have a chance to practice examples using a computer simulation that changes the variables within the gas laws. The **third** day the students would do a lab experiment determining the molar mass of hydrogen collected over water. The **fourth** day would include an assessment (quiz) of the concepts learned to date using a new set of variables with computer simulation.

Which scenario for the Gas Laws lesson would you choose?

[__] Scenario 1

[__] Scenario 2

CONTINUED

LESSON 3: ACIDS AND BASES

SCENARIO 1: This unit would be started with a description of the objectives of the unit and what students would need to know. This would be followed by the teacher outlining the historical background of acids and bases and a description of the three major theories of acids and bases. A contrast between Arrhenius, Bronsted-Lowry, and Lewis Theories would be used to develop characteristic properties such as acids tasting sour, litmus colors, and conductivity. The **second** day would be a lab using household acids and bases and mixing them with indicators to confirm the theories learned in class. The **third** day would be a film on everyday applications of acids and bases in the home and in industry. One example of such a film would be part 16 of the World of Chemistry series. This would be followed by a class discussion of what was seen in the film. The **fourth** day would include an assessment (quiz) of the knowledge learned to date.

SCENARIO 2: This unit would be started with students being asked to write their definitions of acids and bases. They would then begin working in small groups mixing common household products with indicators. They would then be asked to write any changes to their definitions and write down the steps they used in making any changes. The **second** day each group would share their findings with the other groups. Other household examples would then be shown and groups asked to predict their classification based on the definitions the students generated earlier. The **third** day would be a lab using household products as the acids and bases. If time allowed, they would also be shown the demonstration of three flasks where blowing into one causes a blue color, another changes yellow, and the third forms a white precipitate. Students would be expected to write an explanation of the changes observed in the light of their definition of acid-base theory. The **fourth** day would include an assessment (quiz) of the concepts learned to date using new situations

Which scenario for the Acids and Bases lesson would you choose?

[__] Scenario 1

[__] Scenario 2

PART 2: EVERYDAY STRATEGIES

In each section below, please rank order **within each section** the strategies that you think are the **most** important to lesson development using #1 as the most important. Your choices should be what you think is ideal and assuming you have all of the equipment, supplies, and support necessary for your choices.

Rank order the choices in this section from 1 (the most important) to 8 (the least important).

INTRODUCTION TO A UNIT

[ ] Give students a list of behavioral objectives before beginning the unit
[ ] Give students an oral overview of what they will be learning in the unit
[ ] Administer a written pre-test of knowledge of a topic for the unit
[ ] Provide advanced organizers of some type such as an outline for notes or a grid to complete
[ ] Start the unit with an attention-grabbing demonstration
[ ] Start the unit with a lab experiment
[ ] Have students describe what they know about a topic orally, written, or pictorially such as with a concept map
[ ] Have students read and outline the chapter

Rank order the choices in this section from 1 (the most important) to 8 (the least important)

AT THE CONCLUSION OF THE UNIT

[ ] Administer an essay test on the material presented
[ ] Administer an objective test on the material presented
[ ] Administer a mixed format test on the material presented
[ ] Administer an essay test on the material presented in new contexts
[ ] Administer an objective test on the material presented in new contexts
[ ] Administer a mixed format test on the material presented in new contexts
[ ] Administer a test that has written and practical parts
[ ] Administer a test that has written parts, simulation parts, and practical parts

CONTINUED

Rank order the choices in this section from 1 (the most important) to 14 (the least important)

WITHIN A UNIT

[ ] Lecture using an overhead projector or chalkboard
[ ] Have students form and defend hypotheses
[ ] Have students perform lab experiments
[ ] Do demonstrations
[ ] Use computer simulations
[ ] Assess frequently such as with daily quizzes
[ ] Use audio visuals, laser disks and/or other technology to show everyday examples
[ ] Use simulations to have students predict outcomes
[ ] Have students explain discrepant events
[ ] Have students complete open-ended lab exercises
[ ] Work in small groups where everyone has equal responsibilities
[ ] Work in cooperative learning groups where student roles are defined
[ ] Have class discussions on the topic and related issues
[ ] Have students describing their thought processes verbally, pictorially, or charting in the form of a concept map or a Vee diagram

PART 3: REASONS BEHIND YOUR CHOICES

In this section, circle how important each statement is for the choices you made in Parts 1 and 2.

	not important	somewhat important	neutral	important	very important
1.) Students need motivational activities	1	2	3	4	5
2.) Students need applications in a lesson	1	2	3	4	5
3.) Students need to explore an idea to whet their appetites	1	2	3	4	5
4.) Students need to interpret ideas for themselves	1	2	3	4	5
5.) These choices fit with the requirements of my department	1	2	3	4	5
6.) These choices fit with ideas about which I have read	1	2	3	4	5
7.) Students need to have a thought provoking demonstration and /or lab to stimulate their explanation of phenomenon	1	2	3	4	5
8.) These choices fit the preferred lesson format of my principal	1	2	3	4	5
9.) Students need to be focused on the topic first.	1	2	3	4	5
10.) Students need a strong framework to organize their learning and they need to be told what they will be learning	1	2	3	4	5
11.) These choices reflect an approach parents like	1	2	3	4	5
12.) Students need to form and defend their own hypotheses	1	2	3	4	5
13.) Students need help in discovering and organizing concepts	1	2	3	4	5
14.) Students need to learn to verbalize their thought processes	1	2	3	4	5
15.) Students learn best by being told the facts, being told them again, and being told again.	1	2	3	4	5
16.) Students need to test their hypotheses in new situations	1	2	3	4	5
17.) These choices reflect the way in which I was taught	1	2	3	4	5
18.) These are effective choices because I have seen them presented by persons whose opinions I respect.	1	2	3	4	5

CONTINUED

PART 4: PROFILE

1. How many years have you been teaching? __________ teaching chemistry? __________
2. How many classes are you teaching this year? ________ how many are chemistry? ________
3. How many years of chemical industry experience do you have? ____________________
4. What is your highest degree completed? ____________ in what subject? ____________
5. To what professional organizations do you belong [ ] NEA [ ] NARST
   [ ] NSTA [ ] SECO
   [ ] ACS [ ] OAS
   [ ] other ____________________
6. How many professional meetings have you attended in the past five years? ____________
7. How do you stay up-to-date with advancements in chemical education?
   - [ ] reading educational journals
   - [ ] reading Journal of Chemical Ed
   - [ ] reading chemistry journals
   - [ ] local teacher discussion group
   - [ ] attending workshops
   - [ ] conventions
   - [ ] summer institutes
   - [ ] summer employment in science
   - [ ] other ____

PART 5: MITIGATING FACTORS

In Parts 1 and 2, you were asked to make your selections based on what you would most likely choose if there were no mitigating factors. What are some of the major factors that change what you **actually** do in your classroom from what you would choose ideally to do?

THANK YOU FOR YOUR HELP , COOPERATION, and VALUABLE INPUT.
PLEASE RETURN IN THE ENCLOSED ENVELOPE WITHIN 5 DAYS.

Rebecca E. Stricklin
University of Cincinnati
Dept. of Curriculum and Instruction
Mail Location #2
Cincinnati, OH 45220-9919

APPENDIX B

THE MAILINGS

University of Cincinnati

College of Education

Department of Curriculum and Instruction

608 Teachers College Building
Cincinnati, Ohio 45221-0002
Phone (513) 556-3600
Fax (513) 556-2483

April 27, 1993

Dear Fellow Chemistry Teachers,

Many recent reports have been published about education and science education in particular. These reports are making an impact on public opinion and in the minds of government and school officials. However, it is first important to discover what strategies teachers in our area would choose and whether these strategies fit the national picture.

You are one of the classroom chemistry teachers in Southwestern Ohio being asked to tell us what strategies you would choose to use in your classroom. In order that the results will truly represent the practices in our area, it is important that each survey be completed and returned. The survey should only take about 15-20 minutes to complete. Please return the completed survey in the return envelope provided **within 5 days**. The return of the questionnaire indicates your consent to use this data in the study.

You are assured of complete confidentiality. The survey has an identification number for mailing purposes only. This is so we may check your name off of the mailing list when your survey is returned. Your name will never be placed on the questionnaire.

The results of this research will be made available to University faculty, workshop presenters, and to any interested educators. You may receive a summary of results by writing "copy of results requested" on the back of the return envelope, and printing your name and address below it. Please do not put this information on the survey itself.

We would be most happy to answer any questions you might have. Please write or call. The telephone number is (513) 451-7381 or (513) 556-3583.

Thank you for your assistance.

Sincerely,

Rebecca E. Stricklin
Project Director

Thaddeus W. Fowler
Associate Professor

May 14, 1993

Dear Fellow Chemistry Teachers,

You are one of the classroom chemistry teachers that was selected to participate in a mail survey to tell us what strategies you would choose to use in your classroom. In order that the results will truly represent the practices in our area, it is important that each survey be completed and returned. As of now, we have not received all of the surveys and it is important that they all be returned.

Please look and see if you might have overlooked it in the mail pile on your desk or please call for an additional form if you cannot find it.

We would be most happy to answer any questions you might have. Please write or call. The telephone number is (513) 451-7381 or (513) 556-3583.

Thank you for your assistance.

Sincerely,

Rebecca E. Stricklin
Project Director

University of Cincinnati

College of Education

Department of Curriculum and Instruction

608 Teachers College Building
Cincinnati, Ohio 45221-0002

May 29, 1993

Dear Fellow Chemistry Teachers,

About four weeks ago, a questionnaire was sent out to selected high school chemistry teachers in the area. As of today, all completed questionaires have not been returned. It is vital that all questionnaires be returned so that a true picture of our area can be formed.

Our research unit has undertaken this study because of the belief that teacher opinions should be taken into account in the planning and development of programs and workshops that will be offered in the future.

I am writing to you again because of the significance each questionnaire has to the usefulness of this study. In order for the results of this study to be truly representative of the chemistry teachers in our area, it is essential that each person in the sample return their questionnaire.

In the event that your questionnaire has been misplaced, a replacement and a return envelope have been enclosed. Please return the completed survey in the return envelope provided **within 5 days**. Perhaps you can fill it in as you proctor exams. The return of the questionnaire indicates your consent to use this data in the study

Your cooperation is greatly appreciated.

Sincerely,

Rebecca E. Stricklin
Project Director

P.S. Some people have asked when results will be available. I plan to work on them in June and hope to have them available publicly at the first ACS Education Discussion Group next year which will be Monday, September 20, 1993 at 7:00 p.m. at The Summit Country Day School. Some surplus industrial equipment will be given away that evening as well as other activities. Have a good summer and I hope to see you in September.