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A Comparison Between Teacher-Directed Instruction and Student Self-Directed Study in Physical Science for Undergraduate Elementary Education Majors

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A COMPARISON BETWEEN TEACHER-DIRECTED INSTRUCTION AND STUDENT SELF-DIRECTED STUDY IN PHYSICAL SCIENCE FOR UNDERGRADUATE ELEMENTARY EDUCATION MAJORS

by

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This dissertation submitted by Douglas L. Magnus in partial fulfillment of the requirements for the Degree of Doctor of Education from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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ABSTRACT

Purpose of the Study

The purpose of this research was to compare the learning which occurred in a college physical science class for pre-service elementary teachers between two teaching-learning methods identified as teacher-directed instruction and student self-directed study. The specific areas investigated were: (1) knowledge of physical science content, (2) development and application of the processes of science, (3) attitude toward physical science and (4) attitude toward student self-directed study.

Procedures

The research sample used in this study consisted of 95 elementary education majors enrolled in four sections of Chemistry 327 which is a required physical science course. The control group, consisting of two sections, experienced the teacher-directed method which included an introduction to the topic or experiment by the instructor, small group experimentation, analytical and interpretive discussions of the results of the experiments and discussions of assigned reading materials or problems from the textbook. The experimental group, consisting of two sections, was the student self-directed study method which required the students to design and implement their own mode of learning. All students were given the same topic outline.

Null hypotheses were formulated for each of the four areas under investigation. Data to test the hypotheses were obtained from

the use of four test instruments consisting of: (1) a physical science content test, (2) the Processes of Science Test, (3) a science inventory which was used to evaluate the student's attitude toward physical science and (4) a student self-directed instruction inventory which was used to evaluate the student's attitude toward self-directed study. The research design was modeled according to the Solomon Four-Group Design. One-half of the research sample (subgroups of the experimental and control groups) was pretested at the beginning of the quarter. The entire sample was posttested twice, once at the end of the quarter and again after a period of 10 weeks. The data obtained from these instruments were analyzed using one-way and two-way analysis of variance. The *F* values obtained from these analyses were compared with the critical *F* values that were required for significance at the 0.05 level.

Conclusions

The conclusions derived from the analyses of the data are summarized below.

1. There was no significant difference between the means of the experimental and control groups on the content test at the time of the first posttest. There was a significant difference between the means of the experimental subgroup and control subgroup on this same test at the time of the second posttest. The mean for the experimental subgroup was higher than the mean for the control subgroup. From this result it was concluded that the students in the experimental group retained their knowledge of physical science content better than the students in the control group.

2. There were no significant differences between the means of the experimental and control groups on either of the two posttests for the Processes of Science Test. It was concluded that there was no significant difference between the student's development and application of the processes of science between the experimental and control groups.

3. There were no significant differences between the means of the experimental and control groups on either of the two posttests for the science inventory. It was concluded that there was no significant difference in the students' attitudes toward physical science between the experimental and control group.

4. There was no significant difference between the means of the experimental and control groups on the attitude toward self-directed instruction inventory at the time of the first posttest. There was, however, a significant difference between the means at the time of the second posttest. The mean of the control subgroup was higher than the mean of the experimental subgroup. It was concluded that the control group had a more positive attitude toward self-directed study than did the experimental group.

Recommendations for Further Research

Areas and topics for further research that are recommended by this researcher are:

1. Research is recommended to determine the factors that (1) facilitate learning through student self-directed study, (2) affect the student's attitude toward a subject area, and (3) affect the student's attitude toward the mode of learning.

2. A follow-up study of the teacher education students involved in this research should be conducted to compare the effectiveness of the science programs developed in their elementary classrooms.

3. Research should be conducted to determine the differences in learning and attitudes which result when students have a choice between independent study and a teacher-structured learning environment.

4. Research should be conducted to determine the differences in learning and attitudes resulting from independent study where the comparison is made between student self-designed learning activities, student-selected learning modules and teacher-designed learning activities.

5. Research is recommended for the refinement of instruments that measure attitudes toward science content areas and modes of learning.

6. Research is recommended to develop an instrument designed to measure knowledge and application of the processes of science using physical science items.

7. Research is recommended to determine the relationship of the various sciences studied in the secondary school and success in college science courses for elementary education majors.

CHAPTER I

STATEMENT OF THE PROBLEM

Purpose of the Study

The purpose of this research was to compare the learning which occurred in a college physical science class for pre-service elementary teachers between two teaching-learning methods identified as teacher-directed instruction and student self-directed study.

Significance of the Study

The American Association for the Advancement of Science Commission on Science Education (1970) stated that the impact of technology on life in today's world is often cited as a justification for teaching science. "A knowledge of science is essential for understanding modern society, its achievements and its problems" (Hurd, 1966). He further describes the need for a certain literacy in science in order to cope with the rapidly changing modern scientific world.

Assuming that the inclusion of science in the elementary curriculum is important, the primary consideration becomes the nature of and the effectiveness of the science program. The effectiveness of the science program is primarily dependent upon the competency of the teacher in the area of science.

Although science can be identified as an integral part of the elementary school curriculum there has been reluctance on the part of the elementary school teachers to include science as a regular part of the school day. In a national survey conducted by Blackwood (1964) it was determined that a small but significant percentage of all schools taught science less than 20 minutes a week at almost every grade level. Teacher attitudes toward science may be a factor which determines the amount of time spent on science in class. This was substantiated in a study conducted by Bruce and Eiss (1968). In examining the goals of prospective elementary teachers, Bruce and Eiss found that science was often included, but not necessarily required, and all too often science was rejected. These prospective teachers perceived science as irrelevant to their main goals and thus assigned a low priority to it. For some of these students, science was viewed with apprehension. Pierce (1963) noted apprehension and fear in students in his physical science class.

Soy (1967) concluded that prospective elementary teachers have developed their attitudes toward science prior to entering college. These attitudes were negative to the extent that the student would avoid taking science, if possible.

In a study designed to facilitate an increased commitment of pre-service elementary teachers toward the teaching of science, and an evaluation of the program effectiveness, Cheney (1966) found that the students recognized their weaknesses in science but made very little effort to remove their deficiencies through self-study or extended laboratory investigations.

One of the factors which appeared to cause a reluctance to include science as part of essential learning in all elementary school classrooms was the science background of the teachers. In a study conducted by Wytiaz (1962) 51.1 per cent of the teachers polled felt that their background was insufficient to teach science. The teachers in this study spent an average of one to two hours per week teaching science. Wytiaz found that these teachers had a favorable attitude toward taking additional science courses if they were given released time during the school day.

The results of a study conducted by Victor (1961) showed that science background (familiarity with science content and materials) was a definite factor in a teacher's reluctance to teach science. Almost one-half of the teachers surveyed in Victor's study indicated that a person had to be a science expert in order to teach science in the elementary school. Sixty-one per cent of the total teachers surveyed believed that reluctance to teaching science resulted from the teacher often finding himself in a position where he had to answer a question with "I don't know."

Victor (1961) found that the elementary teachers with the stronger science background devoted more class time to science and used more experimentation in class. Berryessa (1959), researching a related question, found that teachers who had developed particularly effective science programs for children had been stimulated considerably more in science than less effective teachers.

Statements by Richardson _et al._ (1960) and Gega (1968) imply that the backgrounds of elementary education majors in the area of science are weak. They further suggest that changes can and should be made in the pre-service education of elementary education majors to develop stronger backgrounds in science.

In light of these findings, it would seem important for the science educator to try to determine the factors and learning conditions which will best provide the elementary education majors with the necessary background, the enthusiasm and stimulation necessary for these future teachers to provide an effective science program for the young students they will be teaching.

Need for the Study

Guidelines from the American Association for the Advancement of Science Commission of Science Education (1970) contained the following statement:

> Our past experiences and professional commitment allow no other view than that science is important; it is important to teachers, it is important to society, it is important to children. The impact of technology is often cited as justification to teach science, and it is. Knowledge of science and technology and their potential effect on society are important in science teaching. But the mode of thought, the way of looking at the world, the way of solving problems, the way of obtaining knowledge that characterize science are far more important contributions of science to society.

With the above statement formulating the basic objective, five guidelines pertaining to the education of elementary school teachers were described. Four of these guidelines were related to this study. The first guideline relating directly to this study dealt with scientific knowledge.

> The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers provide, as a minimum, an adequate background for the topics taught in elementary schools (American Association for the Advancement of Science Commission, 1970).

The second guideline relating directly to this study dealt with the processes of science. "The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry" (American Association for the Advancement of Science Commission, 1970). The third guideline relating directly to this study dealt with the teacher's attitude.

> Science experiences of elementary teachers should develop in teachers an appreciation for the historical, philosophical, and current significance of science to society, and positive attitudes about science which result in a more objective approach to everyday problems, in improved teaching of science in their classroom as well as increased interest in science-related activities (American Association for the Advancement of Science Commission, 1970).

The fourth guideline relating directly to this study dealt with continuous learning.

> Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching (American Association for the Advancement of Science Commission, 1970).

Considering the breadth of outlook in science, Richardson et al. (1960) stated that elementary education majors are not apt to become specialists in science, but they will use science in their work with children and in the interpretation of their own daily experiences. Richardson further stated that elementary education includes more science than it has in the past and that elementary teachers must be prepared to teach it. This requires that the prospective teacher have a significant grasp of the social impact of science, an understanding of the scientific outlook and the breadth and application of scientific inquiry.

Scope of the Study

The research sample used in this study consisted of 95 elementary education majors enrolled in four sections of a required course in physical science for elementary teachers at St. Cloud State College, St. Cloud, Minnesota, during the winter quarter of the 1971-1972 academic year.

The study was designed to answer the following research questions:

1. Is there a significant difference between the experimental group mean and the control group mean for knowledge of physical science as measured by the physical science content test?
2. Is there a significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Processes of Science Test?
3. Is there a significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory?
4. Is there a significant difference between the experimental group mean and the control group mean in their attitudes toward self-directed study as measured by the student self-directed instruction inventory?

Procedures

This study was concerned with a comparison of student learning and attitude change when two teaching methodologies were applied to a physical science course for elementary education majors. The two methodologies used were a student self-directed or independent study approach and a traditional lecture-laboratory method.

The four factors which were investigated in this comparison were: (1) factual and conceptual knowledge in physical science, (2) application and understanding of the processes of science, (3) attitude toward science, and (4) attitude toward student self-directed study.

Prior to any instruction in any of the sections, one-half of the students in each section were randomly selected for pretesting to insure homogeneity of all sections. The students were given four tests: a science content test, a science process test, and two attitude tests. One of the attitude tests was a measure of the student's attitude toward science, the other was a measure of the student's attitude toward self-directed study.

Following the testing, the students in all sections were given a topic outline to use for the course of study. For a listing of the topics see Appendix A. The students in the traditional lecture-laboratory sections started with the first topic of the outline and continued through the sequence of topics for the duration of the quarter. The students in the self-directed sections were instructed to limit their study to the outlined topics. They could devote as much time and delve as deeply into the topics which seemed most to meet their needs and extend themselves into the areas of most importance and significance to them individually.

The same instructor was responsible for all the sections involved in this experiment and both the experimental and control groups had access to the same equipment. The role of the instructor in the experimental sections was that of a resource person. Roll was not taken in the experimental sections and attendance was not required.

The role of the instructor in the control sections was to make presentations, set up experiments and lead discussions. Roll was not taken in the control sections. However, the students were told that attendance was expected at all class meetings. All of the classes met in the same classroom-laboratory.

At the termination of the winter quarter, all students in the sample were given the first set of posttests. The items used in the posttests were the same as those used in the pretest, but the order was changed through random selection. A second posttest was administered to the sample at the end of spring quarter to determine the extent of the change that existed after a period of ten weeks.

Definition of Terms

Scientific Content.--Facts, concepts and laws of nature which were studied in the physical science course used in the experiment.

Processes of Science--Recognition of adequate criteria for accepting or rejecting hypotheses, evaluation of the general structure of experimental design in science, including the need for controls, repeatability, adequate sampling, and careful measurement.

Attitude Toward Science.--An indication of the student's like or dislike of science.

Attitude Toward Self-Direction.--An indication of the student's like or dislike of self-directed education.

Experimental Sections.--The sections which employed student self-direction or individualized education as the method of instruction.

Control Sections.--The sections in which the lecture-laboratory method of instruction was used.

Limitations and Delimitations

The limitations inherent in this study and delimitations imposed to define the parameters of the study were:

1. The student population was limited to the 95 elementary education majors at St. Cloud State College, enrolled in this researcher's four sections of Chemistry 327 (physical science for elementary education majors) during the winter quarter, 1972.
2. Chemistry 327 (physical science for elementary education majors) is a required course for all elementary education majors.
3. Random assignment of students to sections was determined by college wide registration procedures.
4. This investigation was limited to a time interval of five months between the pretest and the second posttest.
5. This investigation was limited by the attrition of 13 students who did not or were unable to take the second posttest.

6. All students met in the same classroom-laboratory and had access to the same equipment.

7. All students were given the same topic outline for the class and instructed to limit their studies to the topics listed.

8. The study was limited by the four 50-minute periods of instruction per week during the 10 week quarter.

Organization of the Remainder of the Study

The remainder of this research was organized into four chapters. A review of the literature related to this study is presented in Chapter II. Chapter III contains a discussion of the experimental design and statistical procedures used in the analysis of the data, the population, the two teaching methods used, and the instruments used to obtain the data. Chapter IV contains an analysis of the data pertaining to the four factors investigated. The conclusions drawn from the study and recommendations for further research are located in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

This chapter is a review of the literature which is extended to discuss four areas related to this study. The first section discusses science content with respect to elementary education majors. The second section deals with processes of science, the third section discusses the attitude that elementary education majors have toward science, and the fourth section relates information pertaining to individualized study.

The review of literature was limited to the resources available at the libraries of the University of North Dakota and St. Cloud State College, including the ERIC collection and dissertation abstracts. The literature reviewed was limited to the past 30 years.

Knowledge of Science Content

Examination of the literature pertaining to the content aspect of the elementary education major's background makes it apparent that attempts have been made to adequately prepare future teachers to teach science. Moorehead (1965) found in a survey of 125 colleges that gaining knowledge of content was the most prominent objective listed. Paralleling this is a statement by Glass (1967) in which he indicates that becoming familiar with the significant scientific facts upon which the major concepts and theories depend is one of the major aims in studying any natural science.

Considering the previous statements, it would be well to examine the science credit requirements for elementary education majors. Mallinson (1949) reported that as of June 1, 1949, 32 states would certify teachers for the elementary grades without having any courses in science. For the states requiring academic credit in science, the range was from three to twelve semester hours. Only Illinois exceeded this by requiring sixteen semester hours of science or science related courses to fulfill the requirement. Mallinson (1949) reported that in 43 of the 48 states it was possible to act as a specialist or consultant or to supervise the teaching of elementary science without having earned any academic credit in science. Dubins and Chamberlain (1963) surveyed 733 institutions, including private and state universities, private and state colleges and state teachers colleges during the years of 1950 and 1954. The range of required credits determined in their survey was zero to eighteen semester hours. The average was 9.23 semester hours for public institutions and 8.83 for private schools. A total of 28 per cent of the schools surveyed required six or fewer semester hours of science, 56 per cent required eight or less semester hours of science, and 19.9 per cent required twelve hours of science. A total of 92.2 per cent of the sample required twelve or less semester hours of science. Bryant (1963), in a study of 229 member schools of AACTE (American Association of Colleges of Teacher Education) found that the credit hours of science required for elementary education majors ranged from zero to 30.4 semester hours with a mean of 11.8 semester hours.

The types of science courses taken by undergraduate elementary education majors tended to be concentrated in the area of biological science. Moser (1964a) found that out of a sample of 505 teachers who had had college training in science, only 43.6 per cent had taken some physical science. Of those who had taken courses in physical science, 56.3 per cent received this education prior to 1940. In another study Moser (1964b) found that 22 per cent of a group of 1,945 elementary teachers had no science training. Of the 1,516 teachers who had taken some science or science methods course, a methods of science teaching course was the most common entry. Biology was the area in which the greatest number of hours were taken. Moser asked this group of teachers to list the courses which they felt were most necessary for their improvement. In answer to the question, the courses listed in order of frequency were: a methods of teaching elementary science, general biology, astronomy, physical science, introductory physics, and general chemistry. Victor (1961) found that elementary teachers thought that chemistry was the most difficult subject to teach followed in order by physics, astronomy, and geology. When this group of teachers was asked which courses would be of most value, they responded, in order, with biology, geology, chemistry, physics, and astronomy. Victor (1961) reported that "this rank order corresponded closely with the list of science courses most commonly taken in college."

Numerous research studies (Hardin, 1965; Beringer, 1965; Hone, 1969; Blackwood, 1964) have shown prospective elementary teachers to be inadequately prepared in terms of science content. Hardin (1965) stated that women showed greater inadequacies than men and primary teachers were less adequately prepared than intermediate teachers. Beringer (1965) concluded that elementary teachers were in need of more education in both the biological and physical sciences. An inadequate background in science is considered by Blackwood (1964) to be a potential barrier to effective science teaching in the elementary school and is considered by Hone (1969) to be reason for not teaching science.

Piltz (1954) found that some of the teachers lacked confidence in teaching science, " . . . due to personal feelings of inadequacy, psychological block and fears related to natural phenomena." Simmons (1959) points out that most elementary teachers have sufficient certification for teaching in the elementary schools, but few have the type of training necessary to provide security in teaching science.

In studying the factors related to competence in science of prospective elementary teachers, Uselton (1963) arrived at the following conclusions:

1. The knowledge of the concepts of science possessed by the elementary teacher candidates was, in general, inadequate to enable them to carry on a well-rounded program in science.
2. The interest in science exhibited by the prospective teacher was very limited.
3. The prospective teachers who planned to teach in the upper grades were more competent in science.
4. The type of science course taken by the teacher candidates seemed to be a factor in the competence of science.

Research studies have produced a variety of comments relating to the science content aspects of the education of an elementary education major. Bruce and Eiss (1968) found that the elementary teachers reported their science content courses to be irrelevant, uninspiring and often overwhelming. The comments from these teachers were more favorable toward the biological sciences than the physical sciences. Bruce and Eiss (1968) also found that many of the teachers showed concern about what to teach by expressing a need for a science "program" in spite of the fact that many new science programs were available. The consequence of this situation was that science became more of a reading exercise than anything else.

Eaton (1966) conducted a study at the University of Texas to determine why so few of the elementary education majors elected science as an area of subject matter concentration. His conclusion was that students lacked insight into the application of a concentration in science subject matter to the process of teaching.

Frankel (1968) found that 50 beginning teachers ranked science content, syllabi, teaching techniques and science teaching concepts as the four most valuable aspects of their methods class. Seventy four student teachers ranked doing experiments, preparing lesson plans, teaching techniques and science content as the four most valuable aspects of their methods class.

In a study involving 100 teachers, Berryessa (1959) found that the total number of accumulated credits in science seemed to be a factor in the kind of science program developed by the teachers.

Many recommendations and suggestions have been made pertaining to the science preparation of elementary education majors. Eiss (1965) has reported the recommendations of the Commission on the Education of Teachers of Science of the National Science Teachers Association. The first group of recommendations came under the basic principle that, "Content and process in science are inseparable."

Methodology should be consistent with the nature of science." Eiss reported the commission's recommendations as:

1. The process approach should be used and defined in teaching content.
2. Laboratory work should be an integral part of the instructional program.
3. Laboratory experiences should be open ended.
4. Group analysis of laboratory sciences is a requisite.

The second principle (Eiss, 1965) that headed a group of recommendations was "A sequential science program for prospective elementary teachers begins with so-called general education science courses." Under this principle, the Commission suggested that the prospective elementary education major take at least twelve hours of general education science courses which would be prerequisite to second level science courses. The second level science courses should be designed for the elementary education major who wishes to pursue science in greater depth. Finally, the professional courses, including science methods, should be structured to provide the college student with the opportunity to work with children in a classroom setting.

Discussing the teacher of the future, Jacobson (1967) states:

> Our teachers of the future will have a fine operational understanding of the broad generalizations of science. . . . He will have a mental picture of man and the world that is generally consistent with that developed in the various sciences. He also will have an understanding of the conceptual structure of science.

Jacobson (1967) continues by describing areas which will have to be emphasized:

1. Future teachers should develop an understanding of the scientific view of man and his world. For example, these teachers should have a conceptual understanding of the conservation laws, and how they operate in the various sciences. . . .
2. The conceptual structure of science should be emphasized. Teachers will have firsthand experience in developing

> operational definitions in science and in studying the interrelationships between definitions. They will study a variety of physical and biological systems and will develop operational concepts of the broad generalizations of science. . . .

A summary of the reasons which determine what science courses elementary education majors take in college center around three factors: (1) the graduation requirement of the college and/or the certification requirements of the state, (2) the selection of general education courses, and (3) general interest in and attitude toward science.

Processes of Science

The first section of this chapter was devoted to science content. Science, however, is more than content, it is more than an accumulation of facts and laws. It includes a methodology that is useful in solving problems, this methodology is commonly referred to as process. Conant (1947) stated that men who have been successful in scientific investigations have depended heavily upon the processes used in their investigations. According to Glass (1967) the second major objective in studying any natural science is " . . . to know what science really is--to recognize its spirit and appreciate its methods." He goes on to state that science is not magic, but, " . . . it is a way--or really many different ways--of finding out reliable knowledge about all natural phenomena."

The American Association for the Advancement of Science Commission on Science Education has formulated a series of guidelines pertaining to the education of elementary education majors. Guideline III (American Association for the Advancement of Science, 1970) stated, "The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry." This source (AAAS, 1970) continues to list:

> Observation and inference, variables, definitions, measurement, classification, organization of data, constructing hypotheses and generalizations, testing hypotheses, modifying hypotheses and generalizations, verifications, communication, model building . . .

as the skills which collectively characterize the processes of science.

Curtis (1967a) described science as " . . . a procedure of inquiry as well as an organized body of subject matter." He continued " . . . science may be viewed operationally as either a product or a process." Expanding his description of science processes Curtis (1967a) stated:

> The processes of science are simply the procedures which facilitate the maximum utilization of inherited powers of observation, reasoning and communication, common to man as man. As such, they are tools available not only to scientists but also to anyone, at any stage of intellectual development. They are universally applicable to the solution of problems relating to all phases of human endeavor, including those of daily living.

Curtis (1967a and 1967b) cited practice in the use of processes as the essential requirement in the development of these skills.

Burns and Brooks (1970) made the following statement as a description of process:

> Processes belong to a type of objective differing from the cognitive (knowledges, understanding and skills), the affective entities (attitudes, interest and appreciations), and heuristic entities (strategies). Processes, as a type of objective, are specific mental skills which are any of a set of actions, changes, treatments, or transformations of cognitive or affective entities used in a strategy in a special order to achieve the solution of a problem associated with the learning act, the use of learning products, or the communication of things learned. Processes are, more simply, transformational entities.

> Because processes are a type of objective or end product, it is inaccurate to view them, singly or as a group, as a "method of instruction." Processes are mental skills used by learners in learning, in using learning products, and in communicating about things learned.
>
> Processes are what describe what is done with facts and other bits of information.

Hurd (1966) illustrates the importance of the processes of science by pointing out that the acquisition of these skills by young people will provide them with a means of remaining abreast of new knowledge as it is generated throughout their lifetimes. According to Piltz (1964) processes of science form some of the major contributions to the elementary school science curricula which are now emerging. Brehm (1968) concurs with Piltz in stating that emphasis on the processes of science is one of the common features in experimental science programs. Another common feature (Brehm, 1968) is a change in emphasis from science as a content subject to science as a skill subject.

Murphy (1968) examined the development of knowledge, scientific attitude, problem-solving ability and interest in biology by comparing content versus process centered biology laboratories. He found no significant differences between the scores attained by the students in either group on the variables of knowledge, scientific attitude, problem-solving ability and interest in biology.

Lane (1966) devised a paper and pencil instrument to measure the competence of teachers in the processes of science, as described by the American Association for the Advancement of Science program, <u>Science - A Process Approach</u>. This test was administered to 100 elementary teachers from two counties in Florida. Results indicated that 80 per cent of the teachers were classified as having average competence while 7 per cent were classified highly competent and 13 per cent low competence.

Wood (1970) conducted a study involving 443 elementary and secondary (science) education students at five Wisconsin State Universities. The instrument used in this study was the Wisconsin Inventory of Science Processes (WISP). The results of this study showed that secondary education students majoring in science scored significantly higher than students enrolled in either primary or intermediate elementary education. Another aspect of this study was a comparison of the WISP scores with factors which included sex, number of university science credits, years of high school science and average grade in university science courses. The only factor that was significantly related to the WISP score was the average grade in university science courses. Wood concluded that the areas of scientific observations, experimentation and communication of scientific knowledge seemed to be understood by over 90 per cent of the students.

Smith and Cooper (1967) conducted an investigation to determine the frequency of use of various teaching techniques to elementary teachers. They found that the teachers with the most formal study in science used techniques such as demonstration, student experimentation, projects and field trips, with significantly greater frequency than teachers with little or no formal study in science. The techniques of reading and discussing of textbooks were used with a greater frequency by the teachers with the least amount of college training. This study also indicated that there was little difference in the frequency of use of student recording and reporting of observations, teaching techniques which could also be considered processes of science.

The results of the various studies emphasize the need for development of processes in science in the education of elementary teachers. Gega (1968) concludes that process skills should be introduced and practiced as natural and needed activities inherent to the subject. Hurd and Gallagher (1968) concur with Gega in stating that the processes of scientific inquiry should be an integral part of the instruction of prospective elementary teachers. Hurd and Gallagher go on to state:

> It is only reasonable to expect that, if elementary school teachers are to emphasize in their teaching such knowledge skills as observing, measuring, formulating hypotheses, and using numbers, the meaning and significance of these must be a part of their own college education.

Thier (1970) emphasizes the point that many of the new science curriculum projects for the elementary school:

> . . . ideologically convert the classroom from a place where facts are verbally distributed to a laboratory where children make observations, collect data, and search for evidence which indicates regularities in natural phenomena.

This laboratory approach requires a knowledge and understanding of the process skills as a definite part of the education of elementary teachers.

Attitude Toward Science

One of the very important aspects of the education of elementary teachers is their attitude toward the various subject areas encountered. Blosser and Howe (1971) describe the teacher's attitude as one of the factors which will determine "the depth and breadth of the science content background" that the teacher will acquire while in college. Thier (1970) stated that the success of any science program will be affected by the teacher's attitude toward teaching science. In discussing curricular change, Hopman (1964) ascribed the key role of curriculum planner and agent for change to the teacher, with the attitude of the teacher as one of the main factors that is instrumental in bringing about change. Schwirian (1969) concurs with this view by suggesting that the attitudinal set of the classroom teacher is one of the major problems in instituting curricular changes.

Todd (1964) offers the following explanation for the attitudes toward science that are held by many women teachers:

> Women teachers' attitudes toward science grow out of their training and experience in modern society. Although most women teachers may appreciate the importance of science and its achievements, their experience as members of the feminine segment of society and of what is termed the "middle class" may produce certain attitudes which interfere with their ability and desire to teach science effectively.
>
> For instance, the lack of interest, of most women in studying science stems in part from feminine and middle-class mores. The woman teacher who is interested in taking courses in science is the exception rather than the rule.

A quote by Mallinson (1956) was used by Todd to substantiate her position:

> The vast majority of the students in this field point to the discouraging fact that most elementary school teachers have had little or no training in science; the training they do possess is of little value in their work with elementary school children; and, as a result of their lack of training, they "shy away" from teaching science.

Todd further explains that women who do not know the scope of science feel that it is a masculine activity. As a result of this reasoning, women feel that they make themselves conspicuous by showing an interest or proficiency in science and they do not want to make themselves conspicuous.

Several studies have been conducted involving prospective and certified elementary teachers pertaining to their attitude toward science. Bixler (1959) investigated the relationship between the teacher's attitudes toward science and the children's learning. He found that teachers who possess favorable attitudes toward science bring about greater positive change in their pupil's learning.

Oshima (1966) compared a lecture-demonstrations-student-discussion method which emphasized seeing and telling, with an individual investigation method which emphasized doing the experiment. The factors compared were: confidence toward teaching science in the elementary school, attitudes toward science, achievement in science, and student-teaching behaviors in science. He found that neither method produced a significant change in attitude toward science. In a similar study, Lindberg (1971) compared a lecture-demonstration method of teaching with a discovery method of teaching for differences in attitudes. The results of this study showed no significant change in attitude due to method. The attitude of the participants toward science was positive at the beginning and at the end of the experiment.

Kane (1968a) conducted a study to determine the attitudes of prospective elementary teachers toward teaching children in four curriculum areas (language arts, mathematics, science and social studies) and toward these academic areas themselves. Three of the conclusions from this study are as follows:

1. The prospective elementary teachers held positive attitudes toward teaching children, toward teaching children in each of the curriculum areas studied and toward the academic areas themselves.
2. In all cases, the group attitude toward a curriculum area is lower than the group attitude toward teaching children in that area. In only one case--social studies and teaching children social studies--is the difference significant. The difference between mathematics and teaching children mathematics approached the 0.05 level.
3. Perhaps the most surprising result obtained was that no significant differences existed among the group attitudes toward the four areas even though mathematics and social studies evoked somewhat lower scores than did language arts and science.

One of the objectives in another study conducted by Kane (1968b) was to " . . . assess the attitudinal structures of prospective elementary school teachers--toward mathematics and other subject areas in which they will be teaching." The participants in this study were students who had just finished their student teaching assignment. The teaching areas considered were: English, mathematics, science and social studies. These teaching areas were rank ordered by the participants with respect to six general statements. The results of this study were tabulated by this researcher to show the order of first choices for each of the six statements (see Table 1).

The Schwirian Science Support Scale was used in a study by Schwirian (1969) in an effort to determine what personal and professional characteristics of elementary teachers are related to their attitudes toward science. The first hypothesis considered was "Positive attitudes toward science are inversely related to age." Analysis of the data showed a marked difference in the attitudes toward science between the younger teachers and the older teachers and the direction of the difference was an inverse relationship as

TABLE 1

RANKING OF SCIENCE, SOCIAL STUDIES, MATH AND ENGLISH IN RESPONSE TO SIX QUESTIONS

Statements	Science	Social Studies	Math	English
1. I enjoyed my work in this field the most in high school	4	3	2	1
2. This field was the most worthwhile for me to study in high school.	4	2	3	1
3. I enjoyed courses in this field most in college	1	3	2	4
4. I learned the most in courses in this field in college	1	3	2	4
5. I probably will enjoy teaching this subject the most	4	3	2	1
6. I probably will be most competent to teach this subject	4	3	2	1

predicted. The amount of higher education experience was another of the characteristics investigated by Schwirian. She hypothesized that "Positive attitudes toward science are positively related to the amount of higher education experienced by the teacher." The original analysis of the data indicated that the relationship between attitude toward science and the amount of higher education experienced was opposite to that predicted. Further analysis with age held constant caused this relationship to disappear. Therefore, Schwirian concluded that " . . . there is no association between highest academic degree and attitudes toward science."

Schwirian (1969) also hypothesized that "Positive attitudes toward science are positively related to the amount of college course work in science." When the data were analyzed with age controlled it was determined that " . . . there is a significant positive association between hours of college science and attitudes toward science among those teachers under 40 years of age."

Two other hypotheses which were retained by Schwirian (1969) were: (1) "Positive attitudes toward science are positively associated with the individual's number of years of teaching experience," and (2) "Teachers of lower grade levels hold less positive attitudes toward science than teachers of higher grade levels."

Siemankowski (1969) reported on the use of an auto-paced teaching process in physical science for elementary teachers. He found, " . . . attitudes toward science of students studying in the auto-pace teaching process were significantly better than those of students taught the conventional way." Siemankowski further stated "The Auto-Paced Teaching process shows that science concepts can be taught to non-science-oriented college students without having them develop a negative attitude toward science."

Soy (1967) conducted a study to determine the attitudes of prospective elementary teachers toward science as a field of specialty. At this institution the student was required to complete a minimum of 15 semester hours of work in a subject area of his choice. Of the 422 usable responses received in this study, 7.1 per cent had elected science as their subject field. Soy (1971) found:

> Lack of interest in the area, difficulty of college courses in science and lack of high school background were reasons which the respondents felt were most important in their decision not to elect a science subject field.

One of Soy's conclusions was that the feelings of prospective elementary teachers toward science are quite firmly established by the time they arrive at college. These feelings are not likely to be positive enough to cause the students to elect science courses in college if they can be avoided. In discussing Soy's study, Bruce (1969) pointed out that the credibility of her findings was increased because of the substantial number of follow-up interviews.

Victor (1961) found that almost half of the certified teachers in his study felt that a person had to be an expert in order to teach science in the elementary school. The teachers who were part of Victor's study also indicated that this feeling could be a factor in the reluctance of elementary teachers to teach science.

Very few of the studies pertaining to attitudes toward science of elementary teachers contained recommendations as to how attitudes could be changed. One recommendation was presented by Washton (1961) as the result of a study involving 100 teachers in a graduate course in science. He stated:

> To promote the learning of science by elementary school teachers, it is essential that fears be minimized or removed. Getting higher scores on standardized science tests will help reduce fears. Self-achievement is an effective weapon against negative attitudes or fears of teaching science. In addition, there is a gain of scientific information.

Andersen (1971) stated, "The development of favorable attitudes toward science depends on the curriculum and on the teacher's attitude and practices in the classroom." Two suggestions which he put forth for getting at the attitudes of the student are, "The teacher must believe that 90% of the students can learn and be successful," and "To effect positive attitude change a teacher must be enthusiastic and use more indirect than direct teaching behaviors."

Raun and Butts (1967-1968) pointed out:

> Evidence seems to suggest that the opportunity to be an active participant in learning activities, rather than a passive recipient, to be involved in experience opportunities in which the teacher guides rather than tells and to be able to express oneself freely are all factors that lead to increased student interest. If one can become more interested in a subject area, one's attitude toward that subject area is generally improved.

In summary, the attitude of the elementary teacher toward science appeared to affect the following: (1) the depth and breadth of the teacher's science content background, (2) the success of any elementary school science program, (3) the learning of children, and (4) the ability to bring about curricular change within the elementary school.

Student Self-Directed, Independent Study

One of the major goals of education is to establish the necessary conditions that will allow the student to maximize his learning. Howes (1970) stated, "Individualized instructional practices and patterns have been slower to develop in mathematics and science than in reading." Within the last few years, educators have been experimenting with a technique called student self-direction or individualized study.

Glass (1967) comments on the importance of self-directed study from the standpoint of the science teacher. He states "the science teacher must be prepared to engage himself in a never-ending continuation of his education."

The number of studies that have been conducted in the area of individualized study and student self-direction in science is somewhat limited. Combs (1968) conducted a study to determine whether there were any significant differences between an independent study situation and a regular classroom situation in the areas of teacher attitudes, science understanding and critical thinking. His results showed no significant differences, beneficial or detrimental, between the groups for the three areas examined. Oshima (1966) also employed independent study as one of the methods in his study. The areas in which comparisons were made included confidence toward teaching science in the elementary school, attitudes toward science, achievement in science and student teaching behaviors in science. Oshima found no significant difference among the groups in any of the areas listed above.

Good (1971) described the use of a "student-structured" technique that is part of the undergraduate elementary science methods course at Florida State University.

> Opportunities are provided for students to recognize that learning is self-structured and is not accomplished by memorization of facts. These opportunities include a large amount of laboratory work with manipulative materials included in a "kit" students purchase at the beginning of the course.

The students are instructed to do whatever they can think of in order to find out what they can about the system at hand. The instructor communicates with the students during their science activities but in a manner which could be classified as non-directive.

A study conducted by Szabo and Feldhusen (1971) attempted to determine whether there was a relationship between success in an independent study science course at the college level and intellective, personality and biographical variables. They (Szabo and Feldhusen, 1971) stated:

> The focus of this research was the empirical study of selected learning characteristics and their relation to academic success in a well-established structured independent study instructional program called Audio-Tutorial Systems (A-T).

The independent study group was compared with a group taught in a more traditionally organized (T-0) learning system. The instruments used in this study were the Guilford-Zimmerman Temperament Survey, The College Entrance Examination Board, and the variables considered were the following:

(1) Restraint (GZTS)
(2) Ascendance (GZTS)
(3) Sociability (GZTS)
(4) Friendliness (GZTS)
(5) High school rank
(6) SAT - verbal
(7) CEEB - Science
(8) CEEB - Math
(9) High school science average
(10) High school math average
(11) High school social studies average
(12) Sex

Each group was further subidivided into high, middle, and low achievement subgroups (Szabo and Feldhusen, 1971) "on the basis of a first semester predicted grade average developed by the student personnel office." The criteria for this study were the final grades in the A-T and T-0 courses. In terms of the three subgroups used in this study, the results were as follows:

> Mathematics reasoning skills and science achievement (high school science grade) were significantly related to success in the A-T course while verbal aptitude, mathematical computational skills, and restraint were significantly related to success in the T-0 course. This suggested that learners with high predicted achievement, low verbal aptitude scores, and

low restraint scores might learn more effectively under the A-T method in which they listen to repeatable audio-tapes and oral communication is emphasized.

A comparison of the middle achievement subgroups of the A-T and T-0 groups revealed that mathematics computational skills, prior science achievement, and restraint were significantly related to success in the T-0 course. No intellective predictors exhibited a significant relationship with success in the A-T course, suggesting that success in the A-T course is not significantly dependent upon prior science and mathematics accomplishments, nor on the tendency to be serious-minded and responsible.

In the low achievement subgroup as in the case of the high achievement subgroup, verbal aptitude was significantly related to success in the T-0 course and achievement in social studies was significantly related to success in the A-T course. Other factors being equal, this suggests that learners whose achievement is predicted to be low, and who are high in science achievement (relative to social studies achievement) learn more effectively in the T-0 learning environment and vice versa.

Szabo and Feldhusen (1971) concluded that these results must be interpreted very carefully for the following reasons:

1. The design was correlational, thus cause and effect cannot be inferred.
2. The A-T and T-0 courses differed in subject matter (botany vs. zoology) and had different sets of instructors.
3. Subjects who did not voluntarily complete data forms or dropped the course were excluded from the sample thereby possibly biasing the sample used.

This section can be summarized with some statements made by Carnie (1970). "By 1980, society will need a 'new-man'--a flexible, ever-learning, problem-solving type of man." He further states:

> Living and learning need to become synonymous processes. Any design for change in science education must accommodate the evident fact that each human being is unique. The design should, therefore, plan to provide the individual with a wide variety of options from which to learn the processes of science.

These statements carry the implications that the teacher must know and understand the uniqueness of each student and be able to provide opportunities for each student to develop the skills and attitudes necessary for independent learning. This further implies that the teacher must demonstrate these skills and attitudes through his/her own actions.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to compare the learning which occurred in a physical science course for elementary teachers when two different teaching methods were employed. The specific areas of learning which were compared were (1) physical science content, (2) processes of science, (3) attitude toward science, and (4) attitude toward student self-direction. A discussion of the experimental design and statistical procedures used in the analysis of the data, a description of the student population and the teaching methods used, and a discussion of the instruments employed to obtain the data are found in this chapter.

Design of Study

The 95 students who participated in this experiment constituted four separate sections of Chemistry 327. Treatment procedures were randomly assigned to each section. As a result of this assignment the 9:00 A.M. and the 12:00 noon sections comprised the control group and the 11:00 A.M. and 2:00 P.M. sections comprised the experimental group.

The test instruments were administered three times. One-half of the experimental group and one-half of the control group was randomly selected on the first day of class, January 5, 1972. The 47 students selected constituted the pretest sample and were given the pretest battery during the first three days of class. All 95 students were posttested during the third week of March, the end of winter quarter. The posttest was administered a second time to 82 members of the research sample at the end of spring quarter in May. Thirteen members of the original sample were unavailable for the May posttest.

The experimental model for this study was the Solomon Four-Group Design (Campbell and Stanley, 1963) illustrated in Diagram 1.

R	0_1	X	0_2
R	0_3		0_4
R		X	0_5
R			0_6

Diagram 1.--Solomon Four-Group Design.

R represents a section, 0 represents observations, and the X represents the experimental procedure. The pretest observations are 0_1 and 0_3 while 0_2, 0_4, 0_5, and 0_6 are the posttest observations.

The specific model used in this study is shown in Diagram 2.

R_1-A	0_1		0_5	0_9
R_2-B	0_2	X	0_6	0_{10}
R_3-C	0_3		0_7	0_{11}
R_4-D	0_4	X	0_8	0_{12}

Diagram 2.--Modification of Solomon Four-Group Design.

R_1, R_2, R_3, and R_4 represent sections A, B, C, and D, respectively. Section A met at 9:00 A.M., Section B at 11:00 A.M., Section C met at 12:00 noon, and Section D at 2:00 P.M. By random assignment, the control group consisted of sections A and C, and the experimental group consisted of sections B and D.

In order to guarantee homogeneity of the research sample, one-half of each section was pretested. These pretests are represented by 0_1, 0_2, 0_3, and 0_4. Use of one-half of each section allows a researcher to guarantee homogeneity of the research population and still have one-half of the population which has not been sensitized to the research instruments.

The experimental teaching method, represented by X, was applied to sections B and D. At the termination of winter quarter all students in all sections were posttested for the first time. These tests are illustrated by 0_5, 0_6, 0_7, and 0_8 in Diagram 2.

A second posttest, designated 0_9, 0_{10}, 0_{11}, and 0_{12} in Diagram 2, was administered at the end of spring quarter (ten weeks after the first posttest). The purpose of the second posttest was to measure the knowledge of physical science content, the knowledge and application of the processes of science, and the attitudes toward physical science and self-direction after the duration of an additional academic quarter. During the time interval between the first and second posttest the students did not participate further in the learning activities related to this study.

It is pointed out (Campbell and Stanley, 1963) that there are a number of internal and external factors that are potential sources of invalidity with various research designs. The Solomon Four-Group Design allows for control of the following internal factors: history, maturation, testing, instrumentation, regression, selection, mortality, and interaction of selection and maturation. An external factor that is controlled in this design is the interaction of testing with the experimentation.

There is no singular statistical procedure which makes use of all six sets of observations simultaneously in the Solomon Four-Group Design. Because of the asymmetrics of the design, analysis of the variance of the gain scores cannot be used. With reference to Diagram 1, a researcher can treat the posttest scores with a simple 2x2 analysis of variance design as shown below.

	No X	X
Pretested	0_4	0_2
Unpretested	0_6	0_5

The main effect of X can be estimated from the column means; the main effects of pretesting can be estimated from the row means; and the interaction of testing with X can be estimated from the cell means. Analysis of covariance of 0_4 versus 0_2 can also be used if the main and interactive effects of pretesting are negligible.

Statistical Procedures

The responses to all items on all four instruments of the pretest, first posttest and second posttest were put on IBM coding sheets for keypunching. Computer scoring was used for all four instruments used in the three tests. The control and experimental group means were calculated for the pretest, first posttest and second posttest.

The main statistical procedures used in this study were one-way analysis of variance for all three tests and two-way analysis of variance for the two posttests.

One-way analysis of variance provided for a comparison of the means of the experimental and control groups, this measured the effect of the different teaching method used with each group (henceforth called treatment), in terms of each of the dependent variables (physical science content, processes of science, attitude toward physical science, and attitude toward self-direction.) This procedure was employed to compare the two group means from the pretest and both of the posttests for all of the dependent variables.

The second analytical procedure used in this study was two-way analysis of variance. The data were processed using a multiple regression program which was available at the University of North Dakota computer center. This procedure provided comparisons of the pretest to posttest means (time duration), the experimental to control group means (treatment), and the change of means from the pretest to posttest between the experimental and control group (interaction).

F-values were obtained from both of these methods of analysis. The computed *F*-values were then compared with the critical *F*-values found in a standard table (Roscoe, 1969) to determine if a significant difference existed. The 0.05 level of significance was chosen for use in this study to reject a null hypothesis.

The reliabilities of the content and process instruments were obtained by application of the Kuder-Richardson "Formula 20" (KR_{20}) equation. This equation is an integral part of the item analysis program that was used for scoring these two instruments. The KR_{20} equation is applicable when the test items have dichotomous variables. "The value for the reliability is an internal consistency coefficient which gives the best measure of reliability expressed as the correlation between random parallel tests" (Magnusson, 1967). (Random parallel tests refers to various combinations of items from the particular instruments that are compared against each other. Computer processing allows one to consider all possible combinations of items.)

The reliabilities of the attitude instruments were calculated using coefficient alpha. This equation is used when the items have weighted scores. The coefficient alpha equation was incorporated into the summated rating computer program that was used to score the attitude scales.

Student Population

The students in this study were enrolled in the four sections of Chemistry 327 taught by the researcher. Chemistry 327, a physical science course, is required of all elementary education majors at St. Cloud College. This course is offered in multiple sections each quarter of the academic year and both summer sessions.

The selection of students for each section was done through the registration process which allowed seniors to register first, juniors second, sophomores third, and freshmen last, according to a predetermined alphabetical order. The starting point in the alphabet is rotated each quarter and the seniors whose last name started with "O" registered first. The juniors and sophomores whose last names began with "M" reigstered first.

This course, Chemistry 327, is recommended to be taken during the junior year, however, seniors and sophomores may enroll. The two experimental sections contained 8.8 per cent seniors, 69.5 per cent juniors, and 21.7 per cent sophomores. The two control sections consisted of 14.8 per cent seniors, 70.4 per cent juniors, and 14.8 per cent sophomores.

The four sections of Chemistry 327 assigned to the researcher met at 9:00 A.M., 11:00 A.M., 12:00 noon, and 2:00 P.M. and will be referred to as sections A, B, C, and D, respectively. Each section was limited to 25 students because of the space available in the classroom-laboratory.

To acquire some information about the science background of individual students included in the research sample, each student was asked to indicate the science courses that they had taken in high school and college on a 3" x 5" card. This information was tabulated and is shown in four separate tables.

High school science course enrollment data were placed in Table 2. The data were arranged to show the number of students in each section, the number of students who indicated that they had not taken any science courses in high school, and the number of students who had studied some of the science courses commonly offered in high school.

One may determine from the data in Table 2 that 85.4 per cent of the research sample had taken biology, 45.2 per cent had taken chemistry, 20 per cent had taken general science, 6.4 per cent had taken physics, and 3.76 per cent had taken earth science. It is noteworthy that 6.4 per cent of this sample had not taken any science in high school.

TABLE 2

HIGH SCHOOL SCIENCE COURSE ENROLLMENTS

Number of Students in Sections	No science courses	Number of Students Who Had Taken General Science	Earth Science	Biology	Chemistry	Physics
A-23	2	6	1	18	10	1
B-23	3	4	1	17	14	2
C-24	1	3	1	23	9	-
D-25	-	6	-	23	10	3
95	6	19	3	81	43	6

The number of students from each section who had taken three or more of the high school science courses listed above is presented in Table 3.

TABLE 3

NUMBER OF STUDENTS TAKING THREE OR MORE DIFFERENT HIGH SCHOOL SCIENCE COURSES

Number of Students in Sections	Number of Students
A-23	3
B-23	5
C-24	1
D-25	2
Total 95	11

It can be calculated from the data in Table 3 that 11.6 per cent of the research sample had taken three or more different science courses in high school. From this group of eleven students, 7.4 per cent were part of the experimental group and 4.2 per cent were part of the control group.

The number of students from each section who had taken at least one science course at the college level from the areas listed are shown in Table 4.

TABLE 4

COLLEGE LEVEL SCIENCE COURSES

Number of Students in Sections	No science courses	Number of Students Who Had Taken				
		Biology	Chemistry	Physics	Earth Science	Other*
A-23	-	22	3	5	10	3
B-23	-	22	6	11	9	2
C-24	-	23	8	5	10	6
D-25	-	25	7	12	6	2
95	0	92	24	33	35	13

*This category includes courses such as meteorgology, astronomy, and natural science which were taken at other institutions.

It can be calculated from the data in Table 4 that 96.8 per cent of the students in this sample had taken a biology course at the college level. A chemistry course was taken by 25.3 per cent of the sample, a physics course was taken by 34.8 per cent of the sample, and 36.8 per cent of this sample of students took an earth science course. "Other" courses, including meteorology, astronomy, and natural sciences, were taken by 13.7 per cent of the students in the sample. The courses in the "Other" science category were taken at institutions other than St. Cloud State College. Everyone had taken at least one science course. It is interesting to note in Table 4 that 23 (sections B and D) of the 33 (69.5 per cent) students who had taken a physics course were in the experimental group.

The number of students who had taken courses from at least three different science areas at the college level are tabulated in Table 5. The reason for tabulating this information was that a student could complete the general education requirements by taking one mathematics course, two biology courses, and one other science course. The student with this combination of courses will have a more limited background than the one who has taken courses from at least three different areas.

TABLE 5

NUMBER OF STUDENTS TAKING THREE OR MORE DIFFERENT COLLEGE SCIENCE COURSES

Number of Students in Sections	Number of Students
A-23	4
B-23	7
C-24	5
D-25	6
Total 95	21

Of the 95 students in this research sample, only two students had taken a course in each of the areas of biology, chemistry, and physics in high school and again in college.

The reader may have noted that all students in the research sample had taken at least one college level science course (Table 4). To meet the general education requirement at St. Cloud State College, a student working toward a Bachelor of Science degree must take four of the following courses: Biology 101, Biology 104, Chemistry 102, Mathematics 121, Physics 103, Earth Science 206, or Physics 207, or transfer college level equivalent science courses.

Methods of Instruction

The purpose of this research was to compare the learning and attitude changes which occurred in a physical science course for elementary teachers when two different teaching methods were employed. The two teaching methods used were a lecture-laboratory approach and a student self-directed study approach. The method of instruction was randomly assigned to each of the four sections in the research sample. This resulted in sections A and C being identified as the control sections, and sections B and D identified as the experimental sections. The lecture-laboratory approach was used in the control sections and the student self-directed approach was used in the experimental section.

Control Sections

The control sections met four days per week for a period of fifty minutes each day for the ten week quarter. Classes began on January 5, 1972, with the first three periods devoted to pretesting.

During the fourth class period the students were given a list of topics that outlined the material to be studied (Appendix A) and the procedural format for the class was explained. Class procedure for the control sections included an introduction to the topic or experiment, which was given by the instructor, small group experimentation, analytical and interpretive discussions of the results of the experiments, and discussions of assigned reading material or problems from their textbook.

The introductory lectures provided a means for the instructor to communicate with the students for a variety of purposes. These purposes included: the posing of questions which could be answered through experimentation, providing any necessary background information or directions for an experiment, providing any necessary precautions prior to an experiment, answering questions, explaining problems which had been assigned as homework, and discussion of reading assignments.

The small group experimentation portion of the class received the major emphasis. The size of the group ranged from two to four members, depending upon the amount of equipment available. The directions for the experiments were put on a ditto and duplicated so that each member of the group could have his own copy. It was the responsibility of the members of the group to assemble the necessary apparatus, gather and analyze data, and formulate conclusions.

After each small group completed the experiment, the class met as a whole to discuss and analyze the results. Occasionally each group would put its data and results on the chalkboard for class comparisons. The discussion of results would be terminated with a description of where and how the concept being studied could be observed in nature and how the results of the experiment could be applied to everyday-type situations.

The amount of time devoted to each topic was determined by the number of experiments used and the amount of time needed to complete and discuss the experiments. Two periods during the quarter were devoted to testing the topics treated during the class periods.

Experimental Sections

The first six class periods for the experimental sections (sections B and D) were devoted to pretesting and orientation. A pretest which required the first three class periods was given to one-half of each section. A three-period orientation to class procedure followed. The first day of orientation the students were given a topic outline which listed the areas of physical science to which they should devote their study. The list of topics for the control and experimental groups were the same (Appendix A). They were told that they did not have to follow the order of the topic outline but could determine their own ordering of the topics. The students were also told that they could delve as deeply as they desired into the topics. They were encouraged to cover as many topics as possible during the quarter.

During the orientation period the students were told that they would be responsible for developing their own learning experiences and that they were free to choose the mode of learning (reading, discussion, experimentation, projects, or possibly a combination of all of these modes) which best suited each of them. As no text was required for the experimental sections, the students were given a list of reference books available in the library and were encouraged to seek out appropriate sources (Appendix B). Students were also told that experimentation was not required but was suggested as a means of solving any problems encountered in their study. Available equipment and supplies for use in experimentation were shown to them.

To conclude the orientation, the instructor's role as a facilitator was explained. In this role the instructor assisted students in locating equipment when the student was unable to locate what he needed, assisted students with problems and experiments when requested to do so, answered questions which came up in small group discussions when asked, and provided direction in getting started on a topic when asked by a frustrated student.

Attendance was not required of the experimental group. The instructor informed the students that the assigned classroom-laboratory would be available for their use during either of the time periods which would have been scheduled for either experimental section. The instructor also informed the students that he would be available in the classroom during these two time periods for any assistance required by the student. As attendance was completely optional, the number of students using the classroom-laboratory facilities varied from day to day.

Instruments Used in the Study

Four different instruments were used to acquire the data necessary for the comparisons of learning and indications of attitudinal changes. Following is a description of the instruments used in this study.

Content Test

Chemistry 327 is designed to be a physical science course for elementary education majors, with the emphasis on factual and conceptual knowledge of physical science. This course is intended to broaden the student's background in science and is supposed to be taken prior to their science methods course which emphasized a study of some of the new elementary science curriculums (SCIS, ESS, SAPA). The choice of topics to be included in Chemistry 327 is left to the discretion of the instructor. The topics used in Chemistry 327 for purposes of this study can be found in Appendix A.

A survey of the existing standardized physical science content tests (Buros, 1965) revealed that none were appropriate for the purposes of this study. Therefore, it was necessary to construct an instrument to measure the amount of learning that occurred in the area of factual and conceptual knowledge of physical science for the topics listed. The choice of topics was structured so that 50 per cent of the topics were in the area of chemistry and 50 per cent of the topics were in the area of physics.

After deciding on the topics to be included in the study all available standardized chemistry and physics tests were examined for potential test items that would evaluate factual and conceptual knowledge in the prescribed topics. It was determined that items from the chemistry and physics tests of the <u>Cooperative Science Tests</u> were best suited to the needs of this study. Following a consideration of the physical science topics and the available items, it was decided by this researcher to limit the length of the content test to 50 items; 25 in the area of chemistry and 25 in the area of physics. This division of items corresponded to the chemistry-physics division of topics. The content test appears in Appendix C.

Selection of items from other standardized tests improved the face validity of this instrument in that these items have proved useful in measuring knowledge of physical science. A validity coefficient was not determined for this instrument. The reliability of this instrument was estimated by use of the Kuder-Richardson "Formula 20" (KR_{20}) equation and ascertained to be 0.6922.

The content test was administered to 12 randomly selected students from each section thereby forming a pretest population of 48 students. This same test with the items reordered was used as the posttest at the end of winter quarter (March 14, 1972) and again at the end of May. The items were reordered to eliminate any possible response pattern which may have resulted from the pretest.

Process Test

The instrument used to evaluate the processes of science was the Processes of Science Test (POST). This instrument was prepared in conjunction with the Biological Sciences Curriculum Study materials and is published by The Psychological Corporation, New York, New York. This test contains 40 multiple choice items which are biological in orientation. The POST manual (Biological Sciences Curriculum Study, 1965) points out:

> The concerns of the authors were with the methodology of science; the bases for judging facts, principles, and

concepts; the extent to which the student had developed standards for judging or appraising data, the student's ability to interpret qualitative and quantitative data; and his ability to screen and judge the design of experiments. The test measures the ability of students to recognize adequate criteria for accepting or rejecting hypotheses, and to evaluate the general structure of experimental design in science, including the need for controls, repeatability, adequate sampling, and careful measurement.

There were two reasons for using this instrument: first, the validity and reliability had been determined through a field testing procedure and was available in the POST manual, and second, by using this test the problem of classifying test items in terms of content or process was eliminated. The items on the POST were biological in nature and structured to test processes of science.

The POST was a part of the pretest battery and was administered to the same 12 randomly selected students from each section, thereby forming a pretest population of 48 students. The POST was also used as a part of the posttest battery and administered to the entire research population consisting of 95 students. The estimated reliability for this instrument was calculated using the KR_{20} formula and found to be 0.6413.

Science Inventory

The instrument used to evaluate the student's attitude toward science was a Likert Scale developed by Dr. Robert Shrigley of Pennsylvania State University. Shrigley collected a number of comments voluntarily made by students enrolled in an undergraduate course dealing with teaching elementary school science. Using the criteria listed by Edwards (1957) these comments were written in the form of attitude statements. The original instrument, containing

38 statements classified as either positive or negative, was given to 89 students. The possible responses to each statement were: "strongly agree," "agree," "undecided," "disagree," and "strongly disagree." For the positive statements, these responses were given weights of 5, 4, 3, 2, and 1, respectively. These weights were reversed in scoring the negative statements. The raw scores of respondents in the upper and lower 27 per cent became criterion groups whereby the favorable-unfavorable index of each statement could be established. T-scores for the 38 original statements ranged from 0.9 to 9.5.

Edwards (1957) suggests a minimum t-score of 1.75 as a rule of thumb for the selection of statements with a minimum of 25 respondents in each criterion group. Shrigley (1971) had only 24 respondents in each criterion group and as a result of this number, selected only statements with a t-score of 3.8 and above. This produced a total of 14 positive statements and 9 negative statements. The responses from his 89 students were analyzed a second time using the Likert Analysis Program and the resulting t-scores ranged from 3.4 to 9.6. The estimated reliability for this instrument was 0.92.

Shrigley's attitude inventory (Appendix D) was used as a part of the pretest and both posttest batteries. Responses to the items were scored using the same method as described above. A Summated Rating Program, which was available at the University of North Dakota Computer Center, was used to analyze the raw data. The range of t-scores for the 23 items was 1.6 to 8.6. The reliability of this instrument was estimated using the coefficient alpha equation which was part of the summated rating computer program used to score this instrument. The estimated reliability was found to be 0.8834.

Student Self-Directed
Instruction Inventory

The instrument used to appraise the student's attitude toward self-direction was a form of the semantic differential constructed by the researcher. This instrument consisted of a definition of the concept under consideration and twenty-five scales. Ten scales were related to the evaluative factor, nine scales were related to the potency factor and six scales were related to the activity factor.

Attitude was appraised through use of the evaluative factor. The rationale for the use of the evaluative factor is given by Osgood, Suci and Tannenbaum (1957):

> Most authorities are agreed that attitudes are learned and implicit--they are inferred states of the organism that are presumably acquired in much the same manner that other such internal learned activity is acquired. Further, they are predispositions to respond, but are distinguished from other such state of readiness in that they predispose toward an evaluative response. Thus, attitudes are referred to as "tendencies of approach or avoidance," or as "favorable or unfavorable," and so on. This notion is related to another shared view--that attitudes can be ascribed to some basic bipolar continuum with a neutral or zero reference point, implying that they both have direction and intensity and providing a basis for the quantitative indexing of attitudes.
>
> This characterization of attitude as a learned, implicit process which is potentially bipolar, varies in its intensity and mediates evaluative behavior, suggests that attitude is a part--to some authorities, the paramount part--of the internal mediational activity that operates between most stimulus and response patterns. This identification of attitude with anticipatory mediating activity has been made most explicit by Doob (1947) who, casting attitude with the framework of Hullian behavior theory, identified it with the "pure stimulus act" as a mediating mechanism.
>
> Still lacking, however, is an identification and localization of attitude per se within this general system of mediational activity. Our work in semantic measurement appears to suggest such an identification: If attitude is, indeed, some portion of the internal mediational activity, it is by inference from our theoretical

> model, part of the semantic structure of an individual, and may be correspondingly indexed. The factor analyses of meaning may then provide a basis for extracting this attitudinal component of meaning.

In all of their factor analyses, certain sets of bipolar adjectives have appeared as the dominant factors, those accounting for the largest portion of the total variance. This occurrence of factors, judged to be evaluative in nature, was independent of the concept under consideration. Therefore, by choosing the evaluative bipolar adjectives with the highest variance loadings, it is possible to construct an instrument that will be indicative of the student's attitude toward the specific concept.

Two other factors identified by Osgood, Suci and Tannenbaum (1957) are potency and activity. The clarity of these factors is not as specific as the evaluative factor in that the variance loadings for the potency and activity factors are not unique. This division of variance between two or more factors is an indication of a contamination of one factor by a second or third factor.

The procedure used in construction of the instrument to evaluate the student's attitude toward self-directed study is described in the following statements. The first step was the formulation of a definition for the term "student self-directed study." The second step was to identify the sets of bipolar adjectives that would be used in this instrument. Table I in the book <u>The Measurement of Meaning</u> by Osgood, Suci and Tannebaum lists the 50 most frequently used pairs of bipolar adjectives and the variance loadings of each pair for the first four factors. Osgood, Suci and Tannenbaum have identified the first three factors as evaluative, potency and activity, respectively. The main criteria considered in choosing the bipolar adjectives was the variance loading of the adjectives. The other consideration was the number of adjectives to be included for each factor. The main factor in terms of this study was the evaluative factor, however adjectives from the potency and activity factors were also included in order to minimize the probability of the formation of a response set. After considering the number of adjective pairs for each factor and their corresponding variance loadings, it was decided by this researcher to use the ten sets of bipolar adjectives with the highest variance loadings for the evaluative factor, the nine sets of bipolar adjectives with the highest variance loadings for the potency factor and the six sets of bipolar adjectives with the highest variance loadings for the activity factor. The complete instrument contained a total of 25 pairs of bipolar adjectives.

The final step in the construction of this instrument was the ordering and aligning of the individual items. The order of the 25 items was determined by a random selection process. The alignment of the items refers to whether one starts with the positive or negative adjective on the left side of the page. The alignment of each scale was randomly determined. The distance between the positive end and the negative end of each scale was divided into seven equal parts. The directions to the student were the same as those recommended by Osgood, Suci and Tannenbaum (1957). A copy of this instrument is contained in Appendix E.

This instrument was administered to the same 12 students from each section giving a pretest population of 48 students.

Each of the three factors was analyzed separately. The evaluative fac- was the primary consideration for this study because of its relationship to the student's attitude toward self-directed study. The data from the potency factor and the activity factor are not included in this study. The same sets of bipolar adjectives were used in the two posttests. The order and the alignment of the scales was randomly determined for the posttests.

The reliability for this instrument was estimated through use of the coefficient alpha equation. This equation was a part of the summated rating computer program which was used to score the instruments. The estimated reliability was found to be 0.8097.

CHAPTER IV

ANALYSIS OF THE RESEARCH DATA

Hypotheses

The four research questions stated in Chapter I are the basis for the following null hypotheses:

1. There is no significant difference between the experimental group mean and the control group mean for knowledge of physical science content as measured by the content test.
2. There is no significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Process of Science Test.
3. There is no significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory.
4. There is no significant difference between the experimental group mean and the control group mean in their attitudes toward self-directed study as measured by the student self-directed instruction inventory.

These hypotheses were examined three times--at the beginning of the 1972 winter quarter (pretest), the end of the 1972 winter quarter (first posttest), and the end of the 1972 spring quarter (second posttest). To examine the hypotheses, data from the pretest, involving one-half of the research population, were analyzed to insure homogeneity of the sample. Data from the first posttest were analyzed to determine whether there were any significant differences between the groups, due to the treatment, in any of the areas under examination. The second posttest occurred ten weeks after the termination of winter quarter. The data from this testing were analyzed to determine whether change occurred from the pretest to the second posttest.

Pretest

The pretest battery was given to 12 randomly selected students from each of the four sections. One test had to be eliminated because of an invalid answer sheet. One student transferred from an experimental section to a control section prior to the beginning of instruction. This gave a total pretest population of 47 students with 25 students from the control sections and 22 students from the experimental sections.

The mean scores of the experimental and control sections for the four instruments are presented in Table 6. The experimental group means were higher for content, processes of science, and attitude toward physical science than the control group means for the same areas.

The mean scores of the experimental and control groups were compared for each of the instruments through the use of a one-way analysis of variance procedure. An $\underline{F}$ value was calculated as part

TABLE 6

MEAN SCORES ON PRETESTS

Group	Content Test	Processes of Science Test	Instruments Science Inventory	Attitude Toward Self-Directed Instruction Inventory
Experimental	19.9	30.6	73.1	53.1
Control	18.6	30.5	72.8	54.5

of the comparison of the group means for each test. The F values resulting from this analysis are contained in Table 7.

TABLE 7

F VALUES OBTAINED FROM ONE-WAY ANALYSIS OF VARIANCE OF THE PRETESTS

Test	F Value*
Content Test	0.80
Processes of Science Test	0.01
Science Inventory	0.005
Attitude Toward Self-Directed Instruction Inventory	0.33

*With 1 and 45 degrees of freedom an F of 4.06 is needed for significance at the .05 level.

With a critical value of 4.06 required for significance, examination of the F values in Table 7 indicated that there were no significant differences between the mean scores of the experimental and control groups for the four areas tested. Therefore, it can be concluded that the students involved in this study constituted a homogeneous sample.

First Posttest

The first posttest was administered to the research sample at the end of winter quarter. One student's test results were rejected because of invalid responses. This gave a total sample of 94 students, with 47 students in the experimental group and 47 students in the control group.

Data from the first posttest were analyzed using one-way and two-way analysis of variance. One-way analysis of variance was used to compare the experimental group mean and the control group mean. Two-way analysis of variance provided comparisons between the pretest and posttest means (time), between experimental and control group means (treatment), and interaction (which tests for a significant difference in the change of means from the pretest to posttest between the experimental and control groups). *F* values were obtained in both analyses and were compared with the critical values given in standard *F*-tables (Roscoe, 1969) to determine if there were any significant differences for any of the variables.

The mean scores of the experimental and control groups obtained from the first posttest of four instruments are found in Table 8. It can be noted from Table 8 that the control group had higher means in all four areas than the experimental group.

Hypothesis I

There is no significant difference between the experimental group mean and the control group mean for knowledge of physical science content, as measured by the content test.

TABLE 8

MEAN SCORES FOR EXPERIMENTAL AND CONTROL GROUPS FOR THE FIRST POSTTEST

Group	Content Test	Processes of Science Test	Instruments Science Inventory	Attitude Toward Self-Directed Instruction Inventory
Experimental	19.91	30.55	79.21	50.29
Control	21.51	31.04	83.74	54.77

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison are illustrated in Table 9.

TABLE 9

ONE-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR THE CONTENT TEST

Source	Sum of Squares	df	Mean Square	F*
Treatment	59.84	1	59.84	1.93
Error	2845.39	92	30.92	
Total	2905.236	93		

*With 1 and 92 degrees of freedom an *F* value of 3.97 is required for significance at the 0.05 level.

With a critical *F* value of 3.97 needed for significance, the calculated *F* value of 1.93 indicated that there was no significant difference between the experimental group mean and the control group mean for physical science content. It can be concluded that there was no significant difference between the experimental group and control group for knowledge of physical science content.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest data and the post-test data of the 47 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the first posttest, used in the two-way analysis of variance of the content test scores are shown in Table 10.

TABLE 10

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE CONTENT TEST

	Pretest	Posttest	
Experimental	19.86	21.82	20.84
Control	18.59	21.59	20.09
	19.19	21.7	

Examination of Table 10 showed that the 47 students who comprise the pretest group had a pretest mean of 19.19 and a posttest mean of 21.7 for the physical science content test. From this same group of 47 students, the experimental subgroup mean was 20.84 and the control subgroup mean was 20.09 for the physical science content test.

The results of the two-way analysis of variance for the content test of the experimental and control subgroups were placed in Table 11.

With a critical value of 4.07 required for significance, the calculated $\underline{F}$ values of 18.89 for the pretest to posttest comparison

TABLE 11

TWO-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR THE CONTENT TEST

Source	Sum of Squares	df	Mean Squares	F*
Pre-Post	148.13	1	148.13	18.89
Treatment	12.85	1	12.85	1.64
Interaction	6.39	1	6.39	0.815
Subjects	2052.10	46	44.61	
Error	357.75	44	7.84	
Total	2577.22	93		

*With 1 and 44 degrees of freedom an F of 4.07 is needed for significance at the 0.05 level.

indicated a significant difference between the pretest mean and the posttest mean for the content test. It can be concluded that there was a significant increase in the student's knowledge of physical science content from the pretest to the posttest in both experimental and control subgroups. The remaining F values are not significant at the 0.05 level indicating that there was no significant difference between the experimental and control subgroups for treatment or interaction.

Hypothesis II

There is no significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Processes of Science Test.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison are illustrated in Table 12.

TABLE 12

ONE-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR THE PROCESSES OF SCIENCE TEST

Source	Sum of Squares	df	Mean Square	F*
Treatment	5.627	1	5.627	0.34
Error	1509.52	92	16.4	
Total	1515.15	93		

*With 1 and 92 degrees of freedom an F value of 3.97 is required for significance at the 0.05 level.

With a critical F value of 3.97 needed for significance, the calculated F value of 0.34 indicated that there was no significant difference between the experimental group mean and the control group mean for knowledge and application of the processes of science.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest data and the posttest data of the 47 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the first posttest, used in the two-way analysis of variance of the Processes of Science Test scores are shown in Table 13.

Examination of Table 13 showed that the 47 students who comprise the pretest group had a pretest mean of 30.55 and a posttest

TABLE 13

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE PROCESSES OF SCIENCE TEST

	Pretest	Posttest	
Experimental	30.64	30.95	30.80
Control	30.48	31.64	31.06
	30.55	31.32	

mean of 31.32 for the Processes of Science Test. From this same group of 47 students, the experimental subgroup mean was 30.80 and the control subgroup mean was 31.06 for the same instrument.

The results of the two-way analysis of variance for the Processes of Science Test of the experimental and control subgroups were placed in Table 14.

TABLE 14

TWO-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR THE PROCESSES OF SCIENCE TEST

Source	Sum of Squares	df	Mean Squares	F*
Pre-Post	13.79	1	13.79	2.69
Treatment	1.64	1	1.64	0.32
Interaction	4.14	1	4.14	0.808
Subjects	1940.55	46	42.2	
Error	225.49	44	5.12	
Total	2185.61	93		

*With 1 and 44 degrees of freedom, an F value of 4.068 is required for significance at the 0.05 level.

With a critical F value of 4.068 required for significance the calculated F values in Table 14 indicated that there was no significant difference between the pretest to posttest means, the experimental to control group means, or the interaction means. It can be concluded from this analysis that the student's knowledge and application of the processes of science did not change significantly during the time of the experiment nor did significant changes occur to the treatment.

Hypothesis III

There is no significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 15.

TABLE 15

ONE-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR THE SCIENCE INVENTORY

Source	Sum of Squares	df	Mean Square	F*
Treatment	482.647	1	482.647	2.667
Error	16646.648	92	180.941	
Total	17129.292	93		

*With 1 and 92 degrees of freedom, an F value of 3.97 is required for significance at the 0.05 level.

With a critical F value of 3.97 required for significance, the calculated F value of 2.667 indicated that there was no significant difference between the experimental group mean and control group mean for the science inventory. It can be concluded that there was no significant difference between the experimental group and control group in attitudes toward physical science.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest data and the posttest data of the 47 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the first posttest, used in the two-way analysis of variance of the science inventory scores are shown in Table 16.

TABLE 16

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE SCIENCE INVENTORY

	Pretest	Posttest	
Experimental	73.09	80.82	76.95
Control	72.80	81.84	77.32
	72.94	81.36	

Examination of Table 16 showed that the 47 students who comprise the pretest group had a pretest mean of 72.94 and a posttest mean of 81.36 for the science inventory. From the same group of 47 students, the experimental subgroup mean was 76.95 and the control subgroup mean was 77.32 for the science inventory.

The results of the two-way analysis of variance for the science inventory of the experimental and control subgroups were placed in Table 17.

TABLE 17

TWO-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR THE SCIENCE INVENTORY

Source	Sum of Squares	df	Mean Squares	F*
Pre-Post	1668.26	1	1668.26	37.8
Treatment	3.13	1	3.13	0.076
Interaction	10.07	1	10.07	0.243
Subjects	15251.51	46	331.55	
Error	1814.97	44	41.2	
Total	18747.76	93		

*With 1 and 44 degrees of freedom an _F_ value of 4.070 is required for significance at the 0.05 level.

With a critical _F_ value of 4.07 required for significance, the calculated _F_ value of 37.8 indicated that there was a significant difference between the pretest to posttest means for the science inventory. It can be concluded that the student's attitude toward physical science differed significantly from the pretest to the posttest in both experimental and control subgroups. The remaining _F_ values were not significant at the 0.05 level indicating that there was no significant difference between the experimental and control subgroups for treatment or interaction.

Hypothesis IV

There is no significant difference between the experimental group mean and the control group mean in their attitudes toward self-directed study as measured by the student self-directed instruction inventory.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 18.

TABLE 18

ONE-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

Source	Sum of Squares	df	Mean Squares	F*
Treatment	469.146	1	469.146	4.498
Error	9594.187	92	104.284	
Total	10063.33	93		

*With 1 and 92 degrees of freedom an _F_ value of 3.97 is required for significance at the 0.05 level.

With a critical _F_ value of 3.97 required for significance, the calculated _F_ value of 4.498 indicated that there was a significant difference between the means of the experimental group and the control group for the student self-directed instruction inventory. The experimental and control group means were 50.29 and 54.77, respectively. It can be concluded that the students in the control group had a significantly more positive attitude toward student self-directed instruction than did the students in the experimental group.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest data and the posttest data of the 47 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the first posttest, used in the two-way analysis of variance of the student self-directed instruction inventory were placed in Table 19.

TABLE 19

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL, AND INTERACTION MEANS FOR STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

	Pretest	Posttest	
Experimental	53.14	50.36	51.75
Control	54.52	53.2	53.86
	53.87	51.87	

Examination of Table 19 showed that the 47 students who comprise the pretest group had a pretest mean of 53.87 and a posttest mean of 51.87 for the student self-directed instruction inventory. From this same group of 47 students, the experimental subgroup mean was 51.75 and the control subgroup mean was 53.86 for the same instrument.

The results of the two-way analysis of variance for the student self-directed instruction inventory of the experimental and control subgroups were placed in Table 20.

TABLE 20

TWO-WAY ANALYSIS OF VARIANCE OF POSTTEST SCORES FOR STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

Source	Sum of Squares	df	Mean Squares	F*
Pre-Post	94.00	1	94.00	1.87
Treatment	104.20	1	104.20	2.08
Interaction	12.35	1	12.35	0.246
Subjects	6303.25	46	137.03	
Error	2206.54	44	50.15	
Total	8720.37	93		

*With 1 and 44 degrees of freedom, an F value of 4.07 is required for significant at the 0.05 level.

With a critical F value of 4.07 required for significance, the calculated F values contained in Table 20 indicated that there were no significant differences between the pretest to posttest means, the treatment means, and the interaction means for the student self-directed instruction inventory. It can be concluded from these results that there was no significant difference in the student's attitude toward self-direction between the experimental and control subgroup. There was also no significant change in the student's attitude toward self-direction from the beginning of the quarter to the end of the quarter.

The comparison of treatment using two-way analysis of variance was not consistent with the comparison using one-way analysis of variance. The one-way analysis was calculated using the posttest scores for the entire sample. The mean for the control group was 54.77 and the mean for the experimental group was 50.30. The two-way analysis of variance used the means for the portion of the sample that had been pretested. The mean for the control subgroup was 53.86 and the mean for the experimental group was 51.75 for the two-way analysis of variance. The two-way analysis of variance was the more powerful statistical tool in that it accounted for a larger amount of variance. This analysis provided a more accurate interpretation of the results. Therefore, this researcher concluded that there was no significant difference in the student's attitude toward self-directed instruction between the experimental and control groups.

Second Posttest

The second posttest was administered to 82 members of the original research sample at the end of spring quarter. Reasons for the diminished number of students included the following: two students graduated at the end of winter quarter and left the campus, one student had temporarily withdrawn from school for medical reasons, two students were student-teaching off-campus, and eight students refused to return to take the second posttest. Of the 82 students taking the second posttest, 42 were in the control sections and 40 were in the experimental sections.

Two separate analyses were applied to the raw data obtained from the second posttest. First, the means of the experimental and control groups were compared using one-way analysis of variance for each of the instruments. The second analysis employed two-way analysis of variance (time, treatment and subjects). This provided for comparison between pretests and posttests (time), between experimental and control groups (treatment), and interaction, which tests for a significant difference in the change of means from the pretest to posttests between the experimental and control groups. _F_ values were obtained in both analyses and compared with the values given in standard _F_ tables (Roscoe, 1969) to determine if there were any significant differences for any of the variables.

The mean for each group on all four instruments used for the second posttest were placed in Table 21. It can be noted from Table 21 that the control group had higher means than the experimental group in all four areas.

TABLE 21

MEAN SCORES FOR EXPERIMENTAL AND CONTROL GROUPS FOR THE SECOND POSTTEST

	Instruments			
Group	Content Test	Processes of Science Test	Science Inventory	Student Self-Directed Instruction Inventory
Experimental	20.89	30.89	78.52	50.29
Control	21.5	30.95	82.61	53.59

Hypothesis I

There is no significant difference between the experimental group mean and the control group mean for knowledge of physical science content as measured by the content test.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 22.

TABLE 22

ONE-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE CONTENT TEST

Source	Sum of Squares	df	Mean Squares	F*
Treatment	7.38	1	7.38	0.25
Error	2366.10	80	29.58	
Total	2373.48	81		

*With 1 and 80 degrees of freedom, an F value of 3.97 is required for significance at the 0.05 level.

With a critical F value of 3.97 required for significance, the calculated F value of 0.25 indicated that there was no significant difference between the experimental group mean and the control group mean for the content test. It can be concluded that there was no significant difference between the experimental group and control group for knowledge of physical science content.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest and second posttest data for the 40 students remaining in the sample who had been pretested. Seven of the students who had been pretested did not take the second posttest. The pretest to posttest, experimental to control and interaction means for the second posttest, used in the two-way analysis of variance of the content test were placed in Table 23.

TABLE 23

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE CONTENT TEST

	Pretest	Posttest	
Experimental	20.30	22.40	21.35
Control	18.48	21.44	19.96
Total	19.32	21.88	

Examination of Table 23 showed that the 40 students who comprise the pretest group had a pretest mean of 19.32 and a posttest mean of 21.88 for the content test. From this same group of 40 students, the experimental subgroup mean was 21.35 and the control subgroup mean was 19.96 for the same instrument.

The results of the two-way analysis of variance for the content test of the experimental and control subgroups were placed in Table 24.

With a critical value of 4.08 required for significance, the calculated F value of 18.2 indicated a significant difference between the pretest mean and the second posttest mean for the content test. It can be concluded that there was a significant increase in the student's knowledge of physical science content from the pretest to the second posttest in both experimental and control subgroups. Considering the fact that a significant difference existed between the pretest mean and the first posttest mean, it can be concluded that the student's knowledge of physical science content had been retained up to the time of the second posttest.

TABLE 24

TWO-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE CONTENT TEST

Source	Sum of Squares	df	Mean Squares	F*
Pre-Post	140.70	1	140.70	18.22
Treatment	41.54	1	41.54	5.38
Interaction	3.92	1	3.92	.508
Subjects	2087.49	42	49.70	
Error	308.90	40	7.72	
Total	2582.55	85		

*With 1 and 40 degrees of freedom, an F value of 4.08 is required for significance at the 0.05 level.

The calculated F value of 5.38 indicated a significant difference between the experimental subgroup mean and the control group mean for the content test. It can be concluded that the mean score of the experimental group was significantly greater than the mean score of the control group. It can also be concluded from this result that the students in the experimental group had retained their knowledge of physical science content better than the students in the control group.

The means of the content test for the pretest, the first posttest, and the second posttest were placed in Table 25. These scores are from the portion of the sample that was pretested and are the means that were used for the two-way analysis of variance.

TABLE 25

MEAN SCORES OF THE EXPERIMENTAL AND CONTROL GROUPS ON THE PRETEST, FIRST POSTTEST, AND SECOND POSTTEST FOR THE CONTENT TEST

	Pretest	First Posttest	Second Posttest
Experimental	19.9	20.84	21.35
Control	18.6	20.09	19.96

It can be observed from the data contained in Table 25 that the means for the experimental group increased with each test whereas the means for the control group increased from the pretest to the first posttest but then decreased from the first posttest to the second posttest.

Hypothesis II

There is no significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Processes of Science Test.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 26.

With a critical F value of 3.97 required for significance, the calculated F value indicated that there was no significant difference between the experimental group mean and the control group mean for the POST. It can be concluded that there was no significant difference in the student's development and application of the processes of science between the experimental group and the control group.

TABLE 26

ONE-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE PROCESSES OF SCIENCE TEST

Source	Sum of Squares	df	Mean Square	F*
Treatment	0.06	1	0.06	0.002
Error	2181.50	80	27.27	
Total	2181.56	81		

*With 1 and 80 degrees of freedom an F value of 3.97 is required for significance at the 0.05 level.

The data were analyzed a second time using the two-way analysis of variance. This comparison involved only the pretest data and the posttest data of the 40 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the second posttest, used in the two-way analysis of variance of the Processes of Science Test scores were placed in Table 27.

TABLE 27

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE PROCESSES OF SCIENCE TEST

	Pretest	Posttest	
Experimental	30.74	32.85	31.80
Control	30.43	31.30	30.87
	30.58	32.02	

Examination of Table 27 showed that the 40 students who comprise the pretest group had a pretest mean of 30.58 and a posttest mean of 32.02 for the Processes of Science Test. From this same group of 40 students, the experimental subgroup mean was 31.80 and the control subgroup mean was 30.87 for the same instrument.

The results of the two-way analysis of variance for the Processes of Science Test of the experimental and control subgroups were placed in Table 28.

TABLE 28

TWO-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE PROCESSES OF SCIENCE TEST

Source	Sum of Squares	df	Mean Squares	F*
Pre-Post	44.70	1	44.70	8.33
Treatment	18.52	1	18.52	3.45
Interaction	8.10	1	8.10	1.51
Subjects	1792.11	42	42.67	
Error	214.7	40	5.37	
Total	2078.13	85		

*With 1 and 40 degrees of freedom an F value of 4.08 is required for significance at the 0.05 level.

With a critical F value of 4.08 required for significance, the calculated F value of 8.33 for the pretest to posttest comparison indicated that there was a significant difference between the pretest mean and the second posttest mean for the Processes of Science Test. It can be concluded that there was a significant increase in the student's development and application of the processes of science in both the experimental subgroup and the control subgroup from the beginning of the experiment to the time of the second posttest.

The treatment F value of 3.45 indicated that there was no significant difference between the experimental subgroup mean and the control subgroup mean for the Processes of Science Test.

Hypothesis III

There is no significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 29.

TABLE 29

ONE-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE SCIENCE INVENTORY

Source	Sum of Squares	df	Mean Square	F*
Treatment	343.40	1	343.40	2.11
Error	12995.87	80	162.45	
Total	13339.27	81		

*With 1 and 80 degrees of freedom an F value of 3.97 is required for significance at the 0.05 level.

increase in the student's development and application of the processes of science in both the experimental subgroup and the control subgroup from the beginning of the experiment to the time of the second post-test.

The treatment F value of 3.45 indicated that there was no significant difference between the experimental subgroup mean and the control subgroup mean for the Processes of Science Test.

Hypothesis III

There is no significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 29.

TABLE 29

ONE-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE SCIENCE INVENTORY

Source	Sum of Squares	df	Mean Square	F*
Treatment	343.40	1	343.40	2.11
Error	12995.87	80	162.45	
Total	13339.27	81		

*With 1 and 80 degrees of freedom an F value of 3.97 is required for significance at the 0.05 level.

With a critical F value of 3.97 required for significance, the calculated F value of 2.11 indicated that there was no significant difference between the means of the students in the experimental and control groups on the science inventory. It can be concluded that there was no significant difference in the student's attitude toward physical science between the experimental and the control groups.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest data and the posttest data of the 40 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the second posttest, used in the two-way analysis of variance of the science inventory were placed in Table 30.

TABLE 30

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE SCIENCE INVENTORY

	Pretest	Posttest	
Experimental	73.00	80.05	76.52
Control	73.80	80.96	77.00
	73.40	80.53	

Examination of Table 30 showed that the 40 students who comprise the pretest group had a pretest mean of 73.40 and a posttest mean of 80.53 for the science inventory. From the same group of 40 students, the experimental subgroup mean was 76.52 and the control subgroup mean was 77.00 for the same instrument.

The results of the two-way analysis of variance for the science inventory of the experimental and control subgroups were placed in Table 31.

TABLE 31

TWO-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE SCIENCE INVENTORY

Source	Sum of Squares	df	Mean Square	F*
Pre-Post	1213.14	1	1213.14	31.07
Treatment	4.82	1	4.82	0.12
Interaction	7.99	1	7.99	0.20
Subjects	14663.11	42	349.12	
Error	1561.63	40	39.04	
Total	17450.69	85		

*With 1 and 40 degrees of freedom an F value of 4.08 is required for significance at the 0.05 level.

With a critical value of 4.08 required for significance, the calculated F value of 31.07 indicated that a significant difference existed between the pretest mean and the second posttest mean on the science inventory. It can be concluded that there was a significant positive increase in the student's attitude toward physical science in both the experimental subgroup and the control subgroup. The calculated F value of 0.12 for the comparison of experimental subgroup mean to the control subgroup mean indicated that there was no significant difference between the means of the two groups. It can be concluded from this result that there was no significant difference in the student's attitude toward physical science due to the experimental treatment.

Hypothesis IV

There is no significant difference between the experimental group mean and the control group mean in their attitude toward self-directed study as measured by the student self-directed instruction inventory.

The data to test this hypothesis were analyzed using one-way analysis of variance to compare the means between the experimental and control groups. The results of this comparison were placed in Table 32.

TABLE 32

ONE-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

Source	Sum of Squares	df	Mean Square	F*
Treatment	222.48	1	222.48	2.98
Error	5966.49	80	74.58	
Total	6188.96	81		

*With 1 and 80 degrees of freedom an F value of 3.97 is required for significance at the 0.05 level.

With a critical F value of 3.97 required for significance, the calculated F value of 2.98 indicated that there was no significant difference between the means of the students in the experimental group and those in the control group for the student self-directed instruction inventory. It can be concluded that there was no significant difference in the student's attitude toward self-directed study between the students in the experimental group and those in the control group.

The data were analyzed a second time using two-way analysis of variance. This comparison involved only the pretest data and the posttest data of the 40 students who had been pretested. The pretest to posttest, experimental to control, and interaction means for the second posttest, used in the two-way analysis of variance of the student self-directed instruction inventory were placed in Table 33.

TABLE 33

PRETEST TO POSTTEST, EXPERIMENTAL TO CONTROL AND INTERACTION MEANS FOR THE STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

	Pretest	Posttest	
Experimental	53.15	50.00	51.57
Control	53.91	54.87	54.39
	53.55	52.60	

Examination of Table 33 showed that the 40 students who comprise the pretest group had a pretest mean of 53.55 and a posttest mean of 52.60 for the student self-directed instruction inventory. From this same group of 40 students, the experimental subgroup mean was 51.57 and the control subgroup mean was 54.39 for the same instrument.

The results of the two-way analysis of variance for the student self-directed instruction inventory of the experimental and control subgroups were placed in Table 34.

TABLE 34

TWO-WAY ANALYSIS OF VARIANCE OF THE SECOND POSTTEST SCORES FOR THE STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

Source	Sum of Squares	df	Mean Square	F*
Pre-Post	19.55	1	19.55	0.49
Treatment	169.70	1	169.70	4.27
Interaction	90.19	1	90.19	2.27
Subjects	4760.83	42	113.35	
Error	1590.10	40	39.75	
Total	6630.37	85		

*With 1 and 40 degrees of freedom, an F value of 4.08 is required for significance at the 0.05 level.

With a critical F value of 4.08 required for significance, the calculated F value of 4.27 indicated that a significant difference existed between the experimental subgroup mean and the control subgroup mean for the student self-directed instruction inventory. It can be concluded from this result that the students in the control subgroup had a significantly more positive attitude toward student self-directed instruction than did the students in the experimental subgroup.

The comparison using the two-way analysis of variance is inconsistent with the comparison using the one-way analysis of variance. Because the two-way analysis is the more powerful statistical tool, this researcher concluded that there was a significant difference in the student's attitude toward self-direction.

The attitudes of the students in the control group were more positive than the attitudes of the students in the experimental group. The means of the pretest and the two posttests for the experimental and control subgroups that were pretested were placed in Table 35.

TABLE 35
MEAN SCORES OF THE PRETEST, FIRST AND SECOND POSTTESTS, FOR THE EXPERIMENTAL AND CONTROL SUBGROUPS ON THE STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

	Pretest	First Posttest	Second Posttest
Experimental	53.1	51.75	51.57
Control	54.5	53.86	54.39

Examination of Table 35 showed that the means for the experimental subgroup decreased for each testing, and that the means for the experimental subgroup were lower than the means for the control subgroup for each administration of the student self-directed instruction inventory.

Summary of Data Analyses

One-half of the research sample was pretested at the beginning of the experiment and the entire research sample was posttested on two separate occasions. The first posttest occurred at the termination of the winter quarter, and the second posttest ten weeks later. The data obtained from each of the posttests were analyzed two times. The first comparison employed one-way analysis of variance of the mean scores of the experimental and control groups to determine the effect of the experimental treatment. The mean scores from the entire research sample were used for this analysis.

The second analysis employed two-way analysis of variance. This analysis used the data from the one-half of the research sample which had been pretested. Three comparisons were derived from this analysis. They were: (1) a comparison of the pretest mean with the mean of each posttest (change due to time), (2) a comparison of the mean from the experimental group with the mean from the control group (change due to treatment), and (3) interaction (analysis of the change of means between the experimental and control groups from the pretest to the posttest.)

The research hypotheses were tested three times. The pretest data were analyzed to test the hypotheses the first time, the data from the first posttest were analyzed to test the hypotheses the second time, and the data from the second posttest were analyzed to test the hypotheses the third time.

The pretest battery was given to one-half of the experimental group and one-half of the control group to verify the homogeneity of the research sample. Comparison of the means of these two groups on the four instruments used in this study indicated that there was no significant difference between the experimental and control groups. This result guaranteed homogeneity of the research sample.

The first posttest battery was administered to the 95 members of the research sample. The second posttest was administered to only 82 members of the research sample. The results of the analyses of the two posttests will be summarized in terms of each of the research hypotheses.

The first hypothesis tested was: there is no significant difference between the experimental group mean and the control group mean for knowledge of physical science content as measured by the content test. Data from the first posttest were analyzed using one-way and two-way analysis of variance. Results of these analyses yielded a significant difference between the pretest and posttest scores, but no significant difference between the experimental and control group scores. Conclusions drawn from these results were: (1) there was a significant increase in the students' knowledge of physical science content from the pretest to the time of the first posttest, and (2) there was no significant difference between the experimental subgroup and the control subgroup for knowledge of physical science content.

Data from the second posttest were analyzed using one-way and two-way analysis of variance. Results of these analyses were: (1) there was a significant difference between the pretest mean and the second posttest mean and (2) there was a significant difference between the experimental subgroup mean and the control subgroup mean. Conclusions drawn from these results were: (1) there was a significant increase in the students' knowledge of physical science from the beginning of the experiment to the time of the second posttest for both experimental and control groups and (2) there was a significant difference in the amount of knowledge of physical science content retained between the experimental and control subgroup with the difference in favor of the experimental group.

The second hypothesis tested was: there is no significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Processes of Science Test. The data from the first posttest were analyzed using one-way and two-way analysis of variance. Results of these analyses yielded no significant differences between the pretest and posttest means, the experimental and control group means, and the interaction means. From these results it was concluded that there was no significant difference in the students' development and application of the processes of science between the experimental and control groups.

The data from the second posttest were analyzed using one-way and two-way analysis of variance. The results of these analyses yielded a significant difference between the pretest and the second posttest means, but no significant difference between the experimental subgroup mean and the control subgroup mean. Conclusions drawn from these results were: (1) there was a significant increase in the students' knowledge and application of the processes of science from the pretest to the second posttest, and (2) there was no significant difference in the students' knowledge and application of the processes of science between the experimental and control groups.

The third hypothesis tested was: there is no significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory. The data from the first posttest were analyzed using one-way and two-way analysis of variance. The results of these analyses yielded a significant difference between the pretest and the first posttest means but no significant difference between the means of the experimental and control groups. From these results it was concluded that there was a significant positive increase in the student's attitude toward physical science in both experimental and control subgroups during the duration of the quarter. It was also concluded that there was no significant difference in students' attitudes toward physical science between students in the experimental and control groups.

The data from the second posttest were analyzed using one-way and two-way analysis of variance. The results of these analyses yielded a significant difference between the pretest and the second posttest means but no significant difference between the experimental and control group means. The conclusions drawn from these analyses were: (1) there was a significant positive increase in the students' attitude toward physical science between the beginning and termination of the experiment and (2) there was no significant difference in the student's attitude toward physical science between students in the experimental and control groups.

The fourth hypothesis tested was: there is no significant difference between the experimental group mean and the control group mean in their attitudes toward self-directed study as measured by the student self-directed instruction inventory. Data from the first posttest were analyzed using one-way and two-way analysis of variance. Results of these analyses yielded no significant differences between the pretest and posttest means or between the experimental and control group means. Conclusions drawn from these results were: (1) there was no significant change in the student's attitude toward self-directed study from the beginning of the quarter to the end of the quarter, and (2) there was no significant difference in the student's attitude toward self-directed study between students in the experimental and control groups.

The data from the second posttest were analyzed using one-way and two-way analysis of variance. Results of these analyses yielded a significant difference between the experimental and control subgroup means, but no significant diference between the pretest and second posttest scores. Conclusions drawn from these results were: (1) there was no significant change in the student's attitude toward self-directed study for the duration of the experiment, however, (2) students in the control subgroup had a significantly more positive attitude toward student self-directed study than did the students in the experimental subgroup at the termination of the experiment.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this research was to compare the learning which occurred in a college physical science class for pre-service elementary teachers between two teaching-learning methods identified as teacher-directed instruction and student self-directed study. The areas considered in this research were: (1) knowledge of physical science content, (2) development and application of the processes of science, (3) student attitude toward physical science, and (4) student attitude toward self-directed study. This study attempted to answer the following research questions:

1. Is there a significant difference between the experimental group mean and the control group mean for knowledge of physical science content as measured by the content test?
2. Is there a significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Processes of Science Test?
3. Is there a significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory?

4. Is there a significant difference between the experimental group mean and the control group mean in their attitudes toward self-directed study as measured by the student self-directed instruction inventory?

Null hypotheses were formulated from the preceding research questions.

The research sample used in this study consisted of the 95 elementary education majors registered in the four sections of Chemistry 327 assigned to this researcher for the winter quarter, 1972, at St. Cloud State College. The control sections were taught using a lecture-laboratory method which emphasized small group experimentation, analysis and interpretation of experimental results and discussions of assigned reading material and problems from their textbook. The experimental sections used a self-directed study approach which required the student to develop and implement his own learning experience.

The research design for this study was modeled after the Solomon Four-Group design. Basic features of this design were pretesting of part of the sample, application of experimental treatment to two sections and two posttestings of the entire sample. One-half of each section was pretested to guarantee homogeneity of the sample. Two sections of the sample received the experimental treatment during the quarter. The entire sample was posttested at the end of the quarter (March 14, 1972) and again at the end of May.

Four instruments constituted the test battery and were administered for the pretest and the two posttests. The four instruments were: (1) a physical science content test, (2) the <u>Processes of</u>

Science Test, (3) a science inventory which evaluated the student's attitude toward physical science, and (4) a student self-directed instruction inventory which evaluated the student's attitude toward self-directed study.

Data obtained from the four instruments were statistically analyzed using one-way and two-way analysis of variance. One-way analysis of variance was applied to the pretest data resulting in a confirmation of the homogeneity of the research sample. Both statistical procedures were applied to the data from the posttests in order to test the null hypotheses for retention or rejection.

Conclusions

Four hypotheses were tested in this study. The conclusions from the analyses of the data will be enumerated in terms of the four hypotheses.

Hypothesis I

There is no significant difference between the experimental group mean and the control group mean for knowledge of physical science content as measured by the content test was the first hypothesis tested. Two-way analysis of variance of the first posttest data yielded an F value of 1.64 which was less than the critical F value required for significance at the 0.05 level. Therefore, the null hypothesis of no significant difference between the experimental and control group means was not rejected.

The two-way analysis of variance of the second posttest data yielded an F value of 5.38 which was greater than the critical F value required for significance at the 0.05 level, thereby indicating that there was a significant difference between the means of the experimental subgroup and control subgroup. The mean for the experimental subgroup was higher than the mean for the control subgroup at the time of the second posttest. Therefore, the null hypothesis of no significant difference between the experimental and control group was rejected at the 0.05 level of significance.

From these results this researcher concluded that the students in the experimental section retained their knowledge of physical science content better than the students in the control group. From this study it appears that the student self-directed study approach is a more effective teaching strategy than a lecture-laboratory method in terms of long range retention of physical science content.

Hypothesis 2

There is no significant difference between the experimental group mean and the control group mean in the development and application of the processes of science as measured by the Processes of Science Test was the second hypothesis tested. Two-way analysis of variance of the first posttest data yielded an F value of 0.32 which was less than the critical F value required for significance. Therefore, the null hypothesis of no significant difference between the experimental and control group means was not rejected at the 0.05 level of significance.

Two-way analysis of the second posttest data yielded an F value of 3.45. This was also less than the critical F value required for significance. Therefore, the null hypothesis of no significant difference between the experimental and control group means was not rejected at the 0.05 level of significance at the termination of the experiment.

From these results this researcher concluded that both teaching strategies are equally effective in facilitating the development and application of the processes of science.

Hypothesis 3

There is no significant difference between the experimental group mean and the control group mean in their attitude toward physical science as measured by the science inventory was the third hypothesis tested. Two-way analysis of variance of the first posttest data yielded an $\underline{F}$ value of 0.076 which was less than the critical $\underline{F}$ value required for significance. Therefore, the null hypothesis of no significant difference between the experimental and control group means was not rejected at the 0.05 level of significance.

Two-way analysis of variance of the second posttest data yielded an $\underline{F}$ value of 0.12 which was also less than the critical $\underline{F}$ value required for significance. Therefore, the null hypothesis of no significant difference between the experimental and control group means was not rejected at the 0.05 level of significance at the termination of this experiment.

The two-way analysis of variance of the pretest to first posttest and the pretest to second posttest data indicated a significant positive increase in the students' attitude toward physical science. From these results this researcher concluded that the two teaching strategies used were equally effective in facilitating a change in the students' attitude toward physical science.

Hypothesis 4

There is no significant difference between the experimental group mean and the control group mean in their attitude toward self-directed study as measured by the student self-directed instruction inventory was the fourth hypothesis tested. Two-way analysis of variance of the first posttest data yielded an *F* value of 2.08 which was less than the critical *F* value required for significance. Therefore, the null hypothesis of no significant difference between the experimental and control group means was not rejected at the 0.05 level of significance.

Two-way analysis of variance of the second posttest data yielded an *F* value of 4.27 which was greater than the critical *F* value required for significance. Therefore, the null hypothesis of no significant difference between the experimental and control group means was rejected at the 0.05 level of significance.

The two-way analysis of variance of the pretest to posttest scores for both posttests indicated no significant difference in the students' attitudes toward self-direction from the beginning of winter quarter to the end of the quarter and to the time of the second posttest. The pretest means were 53.1 and 54.5 for the experimental and control subgroups, respectively. The means for the second posttest were 51.57 for the experimental subgroup and 54.39 for the control subgroup.

From these results this researcher concluded that the students in the control subgroup had a significantly more positive attitude toward self-directed study than did the students in the experimental subgroup at the termination of the experiment.

Recommendations for Further Research

Areas and topics for further research that are recommended by this researcher are:

1. Research is recommended to determine the factors that (1) facilitate learning through student self-directed study, (2) affect the student's attitude toward a subject area, and (3) affect the student's attitude toward the mode of learning.

2. A follow-up study of the teacher education students involved in this research should be conducted to compare the effectiveness of the science program developed in their elementary classrooms.

3. Research should be conducted to determine the differences in learning and attitudes which result when students have a choice between independent study and a teacher-structured learning environment.

4. Research should be conducted to determine the differences in learning and attitudes resulting from independent study where the comparison is made between student self-designed learning activities, student-selected learning modules and teacher-designed learning activities.

5. Research is recommended for the refinement of instruments that measure attitudes toward science content areas and modes of learning.

6. Research is recommended to develop an instrument designed to measure knowledge and application of the processes of science using physical science items.

7. Research is recommended to determine the relationship of the various sciences studied in the secondary school and success in college science courses for elementary education majors.

APPENDIX A

TOPIC OUTLINE FOR CHEMISTRY 327

Topic Outline for Chemistry 327

I. Forces and Motion

A. Linear
B. Angular

II. Energy and Momentum

A. Potential Energy
B. Kinetic Energy
C. Gravity

III. Fluids and Waves

A. States of Matter
B. Properties of Matter
C. Pressure
D. Bouyancy
E. Wave Properties - Sound, Light

IV. Kinetic Theory of Matter

A. Heat
B. Gas Laws

V. Electricity and Magnetism

A. Static Electricity
B. Alternating and Direct Current

VI. Basic Chemistry

A. Chemical Change
B. Atoms
C. Molecules

VII. Periodic Law

VIII. Acids, Bases, Salts, Solutions

IX. Chemical Reactions

A. Exothermic and Endothermic Reactions
B. Reaction Rates
C. Activation Energy
D. Catalysts

APPENDIX B

REFERENCE BOOKS

REFERENCE BOOKS

A

921 R 933a	Androde, E.N. daC Rutherford and the Nature of the Atom
QC AS 23 Vil	Asimov, Iszac Understanding Physics

B

QC .B125 21	Baez, A.V. The New College Physics
Q .B62 160	Booth, Verne H. Physical Science
QC 171 .B625	Booth, Verne H. The Structure of Atoms
QC .B4135 23	Beiser, A., and Krauskopf, K. Introduction to Physics and Chemistry

C

Q .C3 160 1969	Cable, Getchell, Kadesch, Poppy, Wilson The Physical Sciences
QD .C46 33	CBA Chemical Systems
QC .C48 171	Christenson and Garrett Structure and Change
Q 125 .C57	Conant IB Harvard Case Histories in Exp. Science
Q 160 .C34	Cheranis, Parsens, Ronnelberg Study of the Physical World

F

QC .F47 23	Feynman, Leighton, Sands The Feynman Lectures on Physics

G

608.7 G19f	Garett, Alfred B. The Flack of Genius

QC .G195 23	Gamow, G., and Cleveland, JM Physics, Foundations and Frontiers
QB .G55 500	Glasstones, S. Sourcebook on the Space Science
QC .G29 171	Gamow, George The Atom and its Nucleus
C 540 H21g	Greenstone, Satman, Hallingworth Concepts in Chemistry
QC 171 .G3	Gamow, George Matter, Earth and Sky
Ref 7 QC .G26	Gamow, George Biography of Physics
	<u>H</u>
QC .H757 23	Holton, G, and Roller Foundations of Modern Physical Science
	<u>I</u>
Q 160 E3	IPS
	<u>J</u>
QD .J3 21 1960X	Jaffe, Bernard Crucibles: The Story of Chemistry
QD .G75 453 1965	Johnson and Grunwald Atoms, Molecules and Chem Change
Q .U6 127 J27 1958	Jaffe, Bernard Men of Science in America
	<u>K</u>
QD .Kr 461	Kieffer, William F. The Mole Concept in Chem
HC M17K 500	Krauskopf, Konrad B. Fundamentals of Physical Science
QC .K294 23	Karplus, Robert Introductory Physics
	<u>L</u>
QC .L4X 33	Leighton, Robert B. Exercises in Intro. Physics

R

Q 160	.R67	Rosen, S. Siegfried R and Dennison Concepts in Physical Science
HC 509	R89a	Rusk, Rogers D Atoms, Men and Stars

S

QC 23	.S45 1966	Semat, H. Fundamentals of Physics
QD 31	.577 1963	Sorum, C.H. Fundamentals of General Chemistry
QD 31.2	.S56 1971	Sienko and Plane Chemistry - Study Guide QD .S5 38
QD 33	.S2	Sanderson, R. T. Principles of Chemistry
Q 160	.S55 1965	Slabaugh, W. H. & Butler College Physical Science

W

QC 21	.W629	Weber, Manning, White Basic Physics
QC 23	.W528 1966	White, H. F. Modern College Physics 5th Edition

APPENDIX C

CONTENT TEST

CONTENT TEST

Directions: For each of the following questions, blacken the space under the letter corresponding to the best choice of the given answers.

1. If both the pitch and the volume of the sound from a horn change, which of the following must also change?
   I. The amplitude of the sound waves
   II. The frequency of the sound waves
   III. The wave length of the sound waves

   A. I only
   B. II only
   C. III only
   D. II and III only
   E. I, II, and III

2. Which of the following compounds should be classified as salts?
   I. KCl
   II. $NaHCO_3$
   III. Na_3PO_4

   A. I only
   B. II only
   C. III only
   D. I and II only
   E. I, II, and III

3. The pressure at any point in an open container filled with a liquid depends upon
   A. both the density of the liquid and the depth of the point below the surface.
   B. only the distance of the point from the side of the container.
   C. only the distance of the point from the surface.
   D. both the width of the container and the density of the liquid.
   E. only the width of the container.

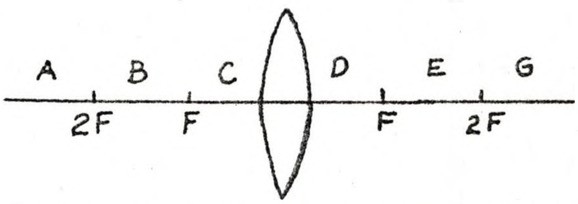
4. Which of the following properties is used to calculate the amount of heat absorbed by the container when a container of water is heated?
   A. Specific heat (cal/gm-C^o)
   B. Coefficient of linear expansion (Δcm/cm-ΔC^o)
   C. Heat of fusion (cal/gm)
   D. Heat of vaporization (cal/gm)
   E. Heat of combustion (cal/gm)

5. Which of the following properties is used to estimate the amount of heat required to melt a sample of pig iron at its melting point?
   A. Specific heat (cal/gm-C^o)
   B. Coefficient of linear expansion (Δcm/cm-ΔC^o)
   C. Heat of fusion (cal/gm)
   D. Heat of vaporization (cal/gm)
   E. Heat of combustion (cal/gm)

6. $C_2H_6 + ...O_2 \xrightarrow{\text{(complete combustion)}}$
   When the reaction above is completed and balanced with the whole-number coefficients, the coefficient in front of O_2 is
   A. 2.
   B. 3.
   C. 5.
   D. 7.
   E. 8.

7. A car is started from rest with a constant acceleration of 4.0 feet per second per second. The distance covered during the first 5.0 seconds is
   A. 10 ft.
   B. 20 ft.
   C. 30 ft.
   D. 40 ft.
   E. 50 ft.

8. A certain element has an atomic number of 11 and an atomic weight of 23. How many protons are there in the nucleus of an atom of this element?
   A. 10
   B. 11
   C. 12
   D. 22
   E. 23



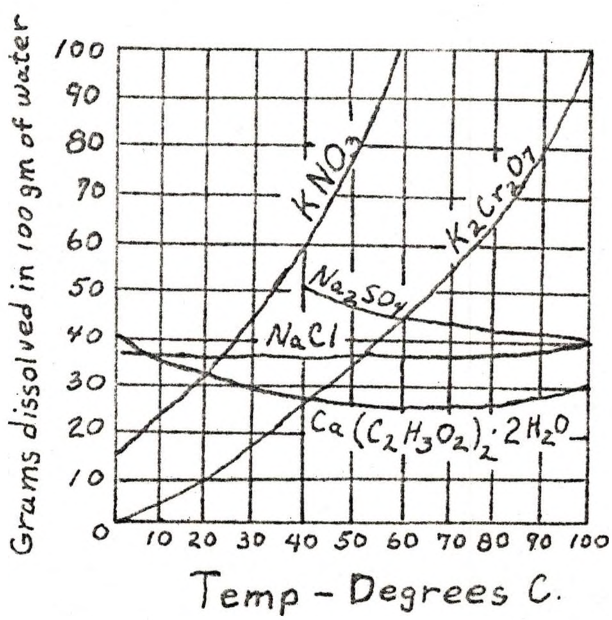
9. Both real and virtual images can be formed by making use of a single convex lens. The diagram above shows such a lens with F denoting the principal focus, 2F a point which is two focal lengths from the lens, and the other letters regions where an object may be placed or an image formed. A real, inverted image smaller than the object can be formed in region E
   A. by placing the object in region A.
   B. by placing the object in region B.
   C. by placing the object in region C.
   D. by placing the object in region G.
   E. under no circumstances with a single convex lens.

10. If the wave motion is a sound wave and a listener starts moving toward the source of sound as the source simultaneously moves toward the listener, there will be an apparent increase in the pitch heard by the listener. This is because the relative motion
   A. decreases the observed frequency and wave length.
   B. increases the observed frequency and wave length.
   C. decreases the observed frequency and increases the wave length.
   D. increases the observed frequency and decreases the wave length.
   E. increases the velocity of sound in the medium.

11. CH_4(gas + $2O_2$(gas) ⟶ CO_2(gas) + $2H_2$(gas)
   (Molecular Weights: CH_4 = 16; O_2 = 32: CO_2 = 44; H_2O = 18)
   The number of liters (at standard conditions of temperature and pressure) of carbon dioxide formed when 8 grams of CH_4 is burned is approximately
   A. 4.
   B. 10.
   C. 20.
   D. 45.
   E. 90.

12. At a given location, two objects of the same mass necessarily have the same
   A. area.
   B. volume.
   C. weight.
   D. density.
   E. composition.

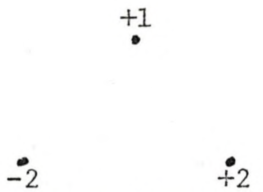
13.



The diagram on the preceding page shows the solubilities of five substances in water at different temperatures. How many grams of sodium sulfate can be dissolved in 100 grams of water at a temperature of 75° C?

A. 38
B. 40
C. 42
D. 44
E. 46

14.



The diagram above shows 3 point charges arranged to form an equilateral triangle, 1 meter on a side. The diagram also shows the sign and magnitude in coulombs of each charge. Which of the following best indicates the direction of the net force on the 1-coulomb charge?

A. 

B. 

C. 

D. 

E. 

15. A student was asked to investigate experimentally a simple pendulum. He knew that the formula $T = 2\pi\sqrt{L/g}$ expressed the relationship between the period T and the length L of a simple pendulum. The minimum apparatus needed to verify by experiment the relationship between the length of a pendulum and its period is a

A. light cord.
B. light cord and a metal ball.
C. light cord, a metal ball, and a watch.
D. light cord, a metal ball, a watch, and a meter stick.
E. light cord, a metal ball, a watch, a meter stick, and a stroboscope.

Questions 16 and 17 refer to the following instructions for an experiment:

Add about 3 milliliters of concentrated hydrochloric acid to about 10 milliliters of sodium silicate solution. Observe the result of this reaction. Filter the gelatinous product formed and wash it with distilled water. The filtrate may be discarded. Remove the gel from the filter, place the gel in an evaporating dish, and heat to dryness.

16. When the acid is added to the sodium silicate solution, a whitish jellylike mass results. This is evidence that
   A. a chemical change has occurred.
   B. a physical, but not a chemical, change has occurred.
   C. an endothermic reaction has occurred.
   D. an exothermic reaction has occurred.
   E. matter has been conserved.

17. The reason for using distilled water rather than tap water to wash the gelatinous product is that
   A. only distilled water is suitable for use in the chemistry laboratory.
   B. compounds are much more soluble in distilled water than in tap water.
   C. distilled water is easier to heat than tap water.
   D. tap water might clog the funnel tube.
   E. impurities in tap water might contaminate the product.

18. Portion of the Periodic Table

I		III				VII	
T		U				V	W
						X	

Hypothetical elements T, U, V, W, and X are located in the upper half of the periodic table of elements shown above. Elements T, U, V, and W are all in the same period, with element T a member of group I, element U a member of group III, element V a member of group VII, and element W the last element in the period. Element X is in the same group as element V and is immediately below it. Which of the following comparisons of elements T and V is correct?
   A. V is more electronegative than T is.
   B. V is more metallic than T is.
   C. Atoms of V have fewer valence electrons than do those of T.
   D. Atoms of V have fewer electrons than do those of T.
   E. Atoms of V are much smaller than are those of T.

19. Which of the following comparisons of elements V and X is correct?
    A. Atoms of V have fewer valence electrons than atoms of X do.
    B. Atoms of V are smaller than those of X.
    C. V is more metallic than X is.
    D. V is much less reactive than X is.
    E. V has a much higher melting point than X does.

20. Atoms least likely to form bonds with other identical atoms would be those of element
    A. T.
    B. U.
    C. V.
    D. W.
    E. X.

21. A sample of impure water contains the following substances:
    I. Ammonia
    II. Salt
    III. Sand

    Which of the impurities would probably be present in the first water condensed during a distillation of the water?
    A. I only
    B. II only
    C. III only
    D. II and III
    E. I and III

22. If a block of gold (specific gravity 19.3) with a volume of 10 cubic centimeters were placed in mercury (specific gravity 13.6), the bouyant force exerted by the mercury on the gold block would be
    A. 5.7 grams.
    B. 10 grams.
    C. 57 grams.
    D. 136 grams.
    E. 193 grams.

23. Which of the following would occur if a moving molecule were to collide with a stationary molecule?
    A. The kinetic energy of both molecules would be unaffected.
    B. Kinetic energy would be lost by the moving molecule and gained by the stationary molecule.
    C. Both molecules would lose kinetic energy.
    D. Both molecules would gain kinetic energy.
    E. Kinetic energy would be gained by the moving molecule and lost by the stationary molecule.

24. A student is to determine the percentage of weight of oxygen in a sample of potassium chlorate. He plans to heat the solid in a test tube. Which of the following entries is <u>not</u> needed for his data table?
   A. Weight of $KClO_3$ and test tube before heating
   B. Weight of test tube
   C. Weight of $KClO_3$ and test tube after heating
   D. Barometric pressure
   E. Loss of weight on heating

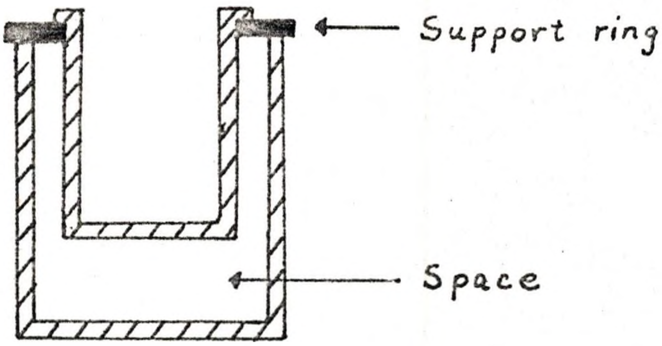
25. A 100-gram piece of glass has a volume of 40 cubic centimeters. Its apparent weight, when submerged in a liquid having a specific gravity of 1.0, is
   A. 140 grams.
   B. 100 grams.
   C. 60 grams.
   D. 40 grams.
   E. 2.5 grams.

26. Which of the following statements helps most to explain the fact that there can be two different substances, ethyl alcohol (C_2H_5OH) and dimethyl ether (CH_3OCH_3), which have the same empirical formula (C_2H_6O)?
   A. In covalently bonded molecules, atoms have fixed positions with respect to one another.
   B. In ordinary chemical changes, matter is neither created nor destroyed.
   C. The percentage composition by weight of a compound is fixed.
   D. A mole of gas occupies 22.4 liters at standard conditions.
   E. Reacting volumes of gases have a whole-number relation to one another under the same conditions of temperature and pressure.

27. The labeled concentration on a bottle of tincture of iodine which has been open on the laboratory shelf cannot be trusted because the
   A. concentration of the iodine has decreased as a result of sublimation.
   B. concentration of the iodine has increased as a result of the solvent.
   C. iodine has been oxidized.
   D. iodine has been reduced.
   E. iodine is efflorescent.

28. An automobile is started from rest with a constant acceleration and obtains a speed of 30 feet per second after 10 seconds. Its acceleration is
   A. 1.5 ft/sec^2
   B. 3 ft/sec^2
   C. 6 ft/sec^2
   D. 32 ft/sec^2
   E. 300 ft/sec^2

29.



A student, desiring to do some experiments to determine the specific heat of various substances, constructed his own calorimeter. He used two tin cans, nexted one inside the other, as shown in the diagram above. The hot sample will be dropped into water held in the inner can. Of the following, the best material to use for the support ring is

A. smooth aluminum.
B. dull, black steel.
C. rough copper.
D. heavy cardboard.
E. the same material as the can.

30. Which of the following concepts helps to account for the relatively high boiling and freezing points of pure water?

A. Valence
B. Covalence
C. Electrovalence
D. Hydrogen bonding
E. van der Waals forces

31. Two small charged pith balls separated by a distance d repel each other with a force F. If the distance between them is doubled, the force of repulsion will be

A. $1/4$ F.
B. $1/2$ F.
C. $1/\sqrt{2}$ F.
D. $\sqrt{2}$ F.
E. 4F.

32. Which of the following is a chemical change?

A. Evaporation of water
B. Distillation of water
C. Freezing of water
D. Electrolysis of water
F. Condensation of water vapor

Questions 33 and 34 refer to the following laws:

I. Charles' law: The volume of a sample of gas at constant pressure varies directly as the absolute temperature.

II. Boyle's law: The volume of a sample of gas at constant temperature varies inversely as the pressure.

III. Avogadro's law: Equal volumes of all gases under the same conditions of temperature and pressure contain equal numbers of molecules.

IV. Law of multiple proportions: When two or more compounds contain the same elements, the weights of one element which are combined with a fixed weight of the others are to each other as small whole numbers.

V. Law of definite composition: In all samples of a pure compound, the same elements are present in a fixed proportion by weight.

In question 38, find the answer to the problem. In question 39, indicate which law or laws above must be used in solving the problem.

33. A 10-liter sample of oxygen at 0°C and 15 pounds per square inch pressure is subjected to 150 pounds per square inch pressure at the same temperature. What is the new volume of the oxygen?
    A. 10/11 liter
    B. 1 liter
    C. 1.1 liters
    D. 2 liters
    E. 100 liters

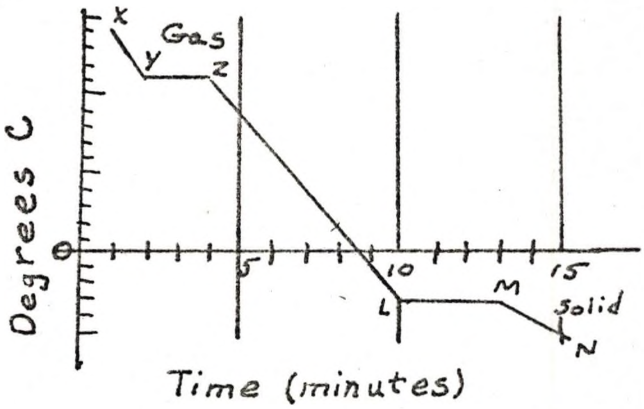
34. Which of the laws must be used in solving the preceding question?
    A. I only
    B. II only
    C. I and II only
    D. I, II, and III only
    E. I, II, III, and IV

35. Several salts, each composed of one positive and one negative ion, are observed in water solution and the colors of the solutions are listed as follows:

Salt	Color of Solution	Salt	Color of Solution
AW	colorless	AX	red
CY	colorless	BW	yellow
EZ	green	DY	blue
CX	red	BY	yellow

These results show that the color of the A ion in solution
- A. is blue.
- B. is green.
- C. is red.
- D. is colorless.
- E. has not been determined.

36.



The graph above represents the continued cooling of a constant mass of a substance at atmospheric pressure. The substance could exist as both a gas and a liquid at a temperature indicated on line segment
- A. XY.
- B. YZ.
- C. ZL.
- D. LM.
- E. MN.

37. A 15.0-milliliter sample of a 1.00-molar solution of HCl will exactly neutralize 15.0 milliliters of a 1.00-molar solution of
    A. $Ca(OH)_2$.
    B. $Mg(OH)_2$.
    C. $Al(OH)_3$.
    D. KOH.
    E. Na_2CO_3.

38. If other factors remain constant, which of the following will produce the strongest electromagnet?
    A. 500 turns and 3 amperes
    B. 700 turns and 2 amperes
    C. 300 turns and 4 amperes
    D. 200 turns and 5 amperes
    E. 100 turns and 10 amperes

39. To determine the focal length of a converging lens, the minimum equipment needed, in addition to the lens, is
    A. a light source.
    B. a light source and a screen.
    C. a light source, a screen, and a meter stick.
    D. a light source, a screen, a meter stick, and a photometer.
    E. a light source, a screen, a meter stick, a photometer, and another lens of known focal length.

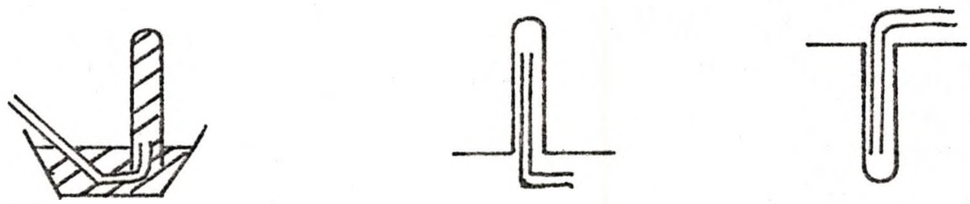
40. A certain element has an atomic number of 11 and an atomic weight of 23. In its most common compounds, the oxidation number or valence for this element would be
    A. -2.
    B. -1.
    C. 0.
    D. +1.
    E. +2.

41. Two satellites with identical masses have large, concentric, circular orbits. If the orbit of the second satellite has a diameter twice that of the first, then the
    A. attraction between the central planet and the second satellite is twice that between the planet and the first satellite.
    B. centripetal force acting on the second satellite is one-fourth that acting on the first.
    C. orbital speed of the second satellite is less than that of the first.
    D. linear momenta of the two satellites are the same.
    E. the period of revolution of the second satellite is shorter than that of the first.

42. If a negatively charged rod is held near an uncharged insulated metal ball, the metal ball
    A. is unaffected.
    B. becomes charged negatively.
    C. becomes charged positively.
    D. has an excess of electrons on the side nearest the charged rod.
    E. has an excess of electrons on the side farthest from the charged rod.

43. An object floating with 2/3 of its volume submerged in a fluid
    A. displaces a volume of fluid equal to its own volume.
    B. would sink deeper into a fluid having a density greater than the original fluid.
    C. could not have a density greater than 1 gram per cm^3.
    D. is bouyed up by a force equal to the weight of the fluid displaced.
    E. would be affected by the same bouyant force even if the object were pushed down deeper into the fluid.

44.



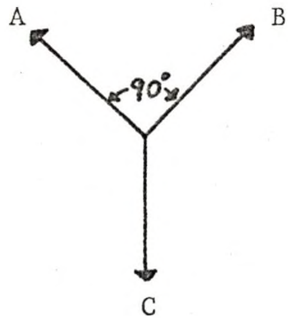
I II III

The diagrams illustrate methods which can be used for the collection of gases.

Of these methods, method II is most likely to be used for collecting
    A. a gas that is soluble in water and lighter than air.
    B. a gas that is soluble in water and heavier than air.
    C. a gas that is insoluble in water and lighter than air.
    D. a gas that is insoluble in water and heavier than air.
    E. none of the four kinds of gases mentioned above.

45. Which of the following will occur if a phonograph record is played at twice the speed at which it was recorded?
    A. All notes will be reproduced at double the frequency of the originals.
    B. The loudness will be doubled.
    C. The low notes will be raised in pitch much more than the high notes.
    D. The amplitude of the issuing sound waves will be halved.
    E. The quality of the sounds will be improved.

46. When two unequal weights are placed on opposite ends of a uniform meter stick, the center of gravity of the system is
   A. nearer the lighter weight.
   B. nearer the heavier weight.
   C. halfway between the two weights.
   D. at the location of the lighter weight.
   E. at the location of the heavier weight.

47. 

Three boys pulling on ropes as shown in the diagram are unable to move one another. Which of the following statements is true regarding the force exerted by each boy?
   A. A is greater than B or C.
   B. B is greater than A or C.
   C. C is greater than A or B.
   D. A = B = C.
   E. None of the above can be concluded from the information given.

48. From the information given below, which of the following compounds would be expected to be most difficult to decompose? (A negative sign means that energy is evolved when the substance is formed from its elements.)

	Compound	Standard Free Energy of Formation, Kilocalories/Mole
A.	H_2O(liquid)	-58.2
B.	H_2O_2(liquid)	-28.2
C.	HBr (gas)	-12.7
D.	HI (gas)	+ 0.3
E.	H_2Se (gas)	+17

49. ....PbO_2 + ...HCl $\longrightarrow$ ....$PbCl_2$ + ...Cl_2 + ...H_2O
When the reaction above is properly balanced with whole-number coefficients, the coefficient in front of HCl is
   A. 2.
   B. 3.
   C. 4.
   D. 5.
   E. 6.

50. CH_4(gas) + $2O_2$(gas) $\longrightarrow$ CO_2(gas) + $2H_2O$(gas)
(Molecular Weights: CH_4 = 16; O_2 = 32; CO_2 = 44; H_2O = 18)
The number of moles of H_2O formed from the burning of 5 moles of CH_4 is
   A. 4.
   B. 10.
   C. 20.
   D. 45.
   E. 90.

APPENDIX D

SCIENCE INVENTORY

Student No. _________

SCIENCE INVENTORY

Directions:

This is not a test. You are to indicate your feelings toward the subject of science. You may react to the statements in one of five ways:

A - Strongly Agree
B - Agree
C - Undecided
D - Disagree
E - Strongly Disagree

Blacken the space below the letter of your choice.

A	B	C	D	E		
"	"	"	"	"	1.	I daydream during science classes.
"	"	"	"	"	2.	I would like to have chosen science as a minor in my elementary education program.
"	"	"	"	"	3.	I dread science classes.
"	"	"	"	"	4.	Science equipment confuses me.
"	"	"	"	"	5.	Science is not an important subject in the elementary curriculum.
"	"	"	"	"	6.	I enjoy manipulating science equipment.
"	"	"	"	"	7.	I am afraid that young pupils will ask me science questions that I cannot answer.
"	"	"	"	"	8.	In science classes, I enjoyed lab periods.
"	"	"	"	"	9.	Science is my favorite subject.
"	"	"	"	"	10.	If given the choice in student teaching, I would prefer teaching science over any other subject of the elementary school.
"	"	"	"	"	11.	My science classes have been boring.
"	"	"	"	"	12.	I would enjoy helping children construct science equipment.
"	"	"	"	"	13.	When I become a teacher, I fear that the science demonstrations will not work in class.

A	B	C	D	E		
"	"	"	"	"	14.	I am looking foward to teaching science to elementary children.
"	"	"	"	"	15.	I enjoy college science courses.
"	"	"	"	"	16.	I prefer that the instructor of a science class demonstrate equipment instead of expecting me to manipulate it.
"	"	"	"	"	17.	I would be interested in working in an experimental elementary science curriculum project.
"	"	"	"	"	18.	I enjoy discussing science topics with my friends.
"	"	"	"	"	19.	Science is very difficult for me to understand.
"	"	"	"	"	20.	I expect to be able to excite students about science.
"	"	"	"	"	21.	I frequently use scientific ideas or facts in my personal life.
"	"	"	"	"	22.	Pre-supposing adequate knowledge about science, I would enjoy teaching the subject to children.
"	"	"	"	"	23.	I believe that I have the same scientific curiosity as children.

APPENDIX E

STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

Student No. ________

MEASURING MEANING

INSTRUCTIONS

The purpose of this study is to measure the meaning of a concept to various people by having them judge the concept against a series of descriptive scales. In taking this test, please make your judgments on the basis of what the concept means to you. On the following page you will find a concept to be judged and beneath it a set of scales. You are to rate the concept on each of the scales in order.

Here is how you are to use these scales: If you feel that the concept at the top of the page is very closely related to one end of the scale, you should place your cross-mark as follows:

rich _X_:__:__:__:__:__:__ poor OR rich __:__:__:__:__:__:_X_ poor

If you feel that the concept is quite closely related to one or the other end of the scale (but not extremely), you should place your cross-mark as follows:

rich __:_X_:__:__:__:__:__ poor OR rich __:__:__:__:__:_X_:__ poor

If the concept seems only slightly related to one side as opposed to the other side (but is not really neutral), then you should check as follows:

rich __:__:_X_:__:__:__:__ poor OR rich __:__:__:__:_X_:__:__ poor

The direction toward which you check, of course, depends on which of the two ends of the scale seem most characteristic of the concept you're judging. If you consider the concept to be neutral on the scale, both sides of the scale equally associated with the concept, or if the scale is completely irrelevant, unrelated to the concept, then you should place your cross-mark in the middle space:

rich __:__:__:_X_:__:__:__ poor

IMPORTANT:

1. Place your cross-marks in the middle of the spaces, not on the boundaries:

   rich __:_X_:__:__:__:__X__ poor
   THIS NOT THIS

2. Be sure you check every scale for the concept - do not omit any.

3. Never put more than one mark on a single scale.

4. Do not look back and forth through the items, but try to make each item a separate and independent judgment.

5. Work at fairly high speeds. Do not worry over items, but instead check your first impression, your immediate "feelings" about the item. On the other hand, don't be careless, because we are interested in your true impressions.

The concept to be judged is 'Student Self-Directed Instruction'. This term describes a classroom situation where the student is responsible for choosing and devising his own learning experiences (reading, experimenting, dialogue, working problems) within the prescribed limits of the course content.

STUDENT SELF-DIRECTED INSTRUCTION INVENTORY

dull	__:__:__:__:__:__:__	sharp
bad	__:__:__:__:__:__:__	good
small	__:__:__:__:__:__:__	large
hard	__:__:__:__:__:__:__	soft
ferocious	__:__:__:__:__:__:__	peaceful
ugly	__:__:__:__:__:__:__	beautiful
cold	__:__:__:__:__:__:__	hot
pleasant	__:__:__:__:__:__:__	unpleasant
awful	__:__:__:__:__:__:__	nice
dishonest	__:__:__:__:__:__:__	honest
weak	__:__:__:__:__:__:__	strong
angular	__:__:__:__:__:__:__	rounded
light	__:__:__:__:__:__:__	heavy
active	__:__:__:__:__:__:__	passive
fair	__:__:__:__:__:__:__	unfair
treble	__:__:__:__:__:__:__	bass
slow	__:__:__:__:__:__:__	fast
rugged	__:__:__:__:__:__:__	delicate

sweet	___:___:___:___:___:___:___	sour
deep	___:___:___:___:___:___:___	shallow
soft	___:___:___:___:___:___:___	loud
clean	___:___:___:___:___:___:___	dirty
thin	___:___:___:___:___:___:___	thick
kind	___:___:___:___:___:___:___	cruel
profane	___:___:___:___:___:___:___	sacred

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