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A STUDY OF THE UNDERSTANDING OF SCIENCE PROCESSES IN RELATION TO PIAGET COGNITIVE DEVELOPMENT AT THE FORMAL LEVEL, AND OTHER VARIABLES AMONG PROSPECTIVE TEACHERS AND COLLEGE SCIENCE MAJORS

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A STUDY OF THE UNDERSTANDING OF SCIENCE PROCESSES IN RELATION TO PIAGET COGNITIVE DEVELOPMENT AT THE FORMAL LEVEL, AND OTHER VARIABLES AMONG PROSPECTIVE TEACHERS AND COLLEGE SCIENCE MAJORS

by

Ali Mohamed El-Gosbi

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the Faculty of the Graduate School at
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Approved by

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APPROVAL PAGE

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EL-GOSBI, ALI MOHAMED. A Study of the Understanding of Science Processes in Relation to Piaget Cognitive Development at the Formal Level, and Other Variables Among Prospective Teachers and College Science Majors. (1982) Directed by Dr. Ernest W. Lee. Pp. 179.

This study was designed to answer the following questions: 1) Which of the following variables--cognitive ability, high school and college science experience, college mathematics experience, college grade point average, SAT scores, and age--correlated most frequently with and was useful in explaining science-process understanding among prospective teachers and college science majors? 2) Is there any relationship between science-process achievement and cognitive ability among prospective teachers and college science majors? 3) Is there any significant difference between prospective teachers and college science majors as to their science-process achievement and cognitive ability? 4) Does college-science experience have an effect on science-process understanding among prospective teachers and college science majors?

The sample consisted of 85 subjects: 37 prospective teachers who were early childhood education majors; 23 prospective teachers who were intermediate education majors; and 25 subjects who were the college science majors group.

All subjects were administered the Test of Science Processes (TOSP) and the Test of Logical Thinking (TOLT), to assess their science processes achievement and logical thinking abilities respectively.

Data gathered on the dependent and independent variables were subjected to analysis of variance, Pearson

correlation analysis, simple and stepwise multiple regression analyses to test for statistical significance of the study's 24 hypotheses.

The analysis of data revealed that: 1) Among college students (overall sample subjects) a significant relationship was found between TOLT, SAT, GPA, college and high school science experience, and science processes achievement (TOSP). TOLT, SAT, and GPA in combination, with an ability to explain 41.81% of variability in TOSP, constituted the best significant prediction model of science processes within college students. 2) Among prospective teachers (overall), TOLT, SAT, and GPA were significantly related to science processes achievement (TOSP). TOLT and SAT together accounted for 27.33% of variability in TOSP. Both variables constituted the best significant prediction model of science processes among prospective teachers. 3) Among college science majors group, TOLT and GPA were significantly related to science processes achievement (TOSP). TOLT accounted for 55.36% of variability in TOSP. It alone constituted the best prediction model of TOSP scores among college science majors. 4) College science majors group was significantly superior to prospective teachers who were early childhood education majors on both TOSP and TOLT achievement scores. 5) It was found that college science experience contributed to science processes skills in an indirect way through TOLT.

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CHAPTER I

INTRODUCTION

The scientific method of investigation introduced by Dewey in the 1930s and 1940s has not been emphasized as one of the main science education goals until the reform movement of the 1950s and 1960s. Batten (1976) pointed out:

> Dewey proposed a very basic framework about which science processes could be constructed. His five-step formalistic method included defining a problem, forming an hypothesis, planning a test of the hypothesis, gathering data, and forming conclusions. This framework became an ingredient in the preface to many science textbooks of the period, but largely failed to be implemented until today. (pp. 17-18)

The reform movement in the 1960s in science education, which emphasized an inquiry or problem-solving approach as a way of teaching and learning science (Bybee, 1974), marked the shift away from teaching science as a fixed body of knowledge or facts to be memorized, toward learning science through the processes of scientific inquiry and discovery. Science processes of observing, measuring, hypothesizing, designing, and conducting experiments, inferring, and predicting, were emphasized. The emphasis on such processes, in most of the innovative programs, has become a powerful means aimed at helping the student develop his intellectual abilities and become a scientifically literate person who can think rationally and critically.

Strom and Klein (1979) stated:

> Within the past ten to fifteen years, a number of scientific programs have been produced that emphasized the development of process skills. Examination of many different programs reveals that there is much agreement across programs as to the nature of these processes. Among those most commonly listed are: observing, describing, measuring, interpreting data, using numbers, predicting, inferring, forming hypotheses, and testing hypotheses. Regardless of the number and nature of the process identified in each program, there is general agreement that the development of process skills is central to the contemporary science program. In addition, these skills are seen as being crucial in a much broader context because they are applicable beyond the scope of science to all areas of the curriculum, and even beyond the classroom to the problems encountered in life. (p. 382)

The establishment of inquiry-discovery skills as an important aim in science education gained the support of many influential science educators such as Jerome Bruner and Robert M. Gagné. In his book, The Process of Education, Bruner outlined his science education model, which emphasized knowledge as the dominant aim, and methods of scientific inquiry as the means to achieve this aim (Bybee, 1977). Gagné (1963) also stated that processes such as observation, classification, inferences, and model building are considered to be important by science educators.

In recognition of the importance of science and science process skills for the society, the fifty-ninth Yearbook of the national Society for the Study of Education emphasized the development of problem solving and understanding the nature of science as a major goal of science education. Speaking in harmony with the above stated position and in support for the new trend in science education, the National Science Teacher Association stated in its position statement entitled "School Science Education for the '70's" that promotion of scientific literacy requires a balance between conceptual schemes, science concepts, and processes.

> To promote scientific literacy, science curricula must contain a balanced consideration among conceptual schemes, science concepts, and science processes including rational thought processes, the social aspect of science and technology, and values deriving from science. (Cited by Batten, 1976, p. 8)

This dissertation is designed to gather and analyze data on the understanding of science + processes, Piaget + logical thinking at the formal level, and other academic variables among a group of prospective teachers and science majors.

The new science education trend in developing and practicing science processes skills is aimed at helping the student to become an investigator who can identify a problem, formulate hypotheses, and carry out procedures to test the hypotheses. This trend is being reflected in most of the new science courses at the elementary, secondary, and college levels. These process skills have been defined by Esler (1973) as "the processes of science . . . which scientists or children must do to conduct scientific inquiry" (p. 20).

Such process skills have been identified and arranged by Gagné as follows: the simplest one which includes observing, classifying, using numbers and measuring; the more complex includes using space-time relationships, communicating, predicting, inferring, and defining operationally; to the most complex which includes formulating hypotheses, interpreting data, controlling variables, and experimenting.

As described by Gagné (1965), observations are the ability to observe and identify objects or events, properties, and change in properties, and to observe relations under systematic physical properties' changes. Observations are also what might be seen or inferred when observing through a telescope, microscope, or other scientific means of observation. Measurement is the use of standard units of measurement to measure objects, length, width, volume, weight, and temperature, as well as force, speed, and time. Understanding the difference between nominal, interval, and ratio scales and their applications is also described. Classification is the development of skills to classify objects, actions, and events by means of single or multiple, observed or inferred dimensions.

Formulating and testing hypotheses is the formulation of researchable hypotheses regarding the cause and effect of phenomena under investigation, and the description and carrying out of procedures to investigate such hypotheses and evaluate the results.

Interpretation of data is the proper and intelligent interpretation of data which leads to imaginative and comprehensive conclusions, and avoids drawing unsupported conclusions.

Communication is describing orally, in writing, or both, changes in physical states, motions, color, weight, volume, and area; presentations of scientific information and data through graphic or mathematical symbols; descriptions of the conditions of an experiment in writing, through demonstrations, or statements of purpose.

Inferences and Prediction refers to the use of inference, extrapolations or intrapolation to predict an outcome based on a trend in data, and the ability to distinguish between an observation and an inference.

Piaget's theory of cognitive development, which focuses on how the child's intellectual abilities progress from birth to adulthood, assessment of those abilities at any given stage of development, and how the child goes about learning, has had the most significant effect among other developmental theories on the restructuring of curriculum and instruction in science education. Many modern science curriculum projects such as SCIS, SAPA, ESS, AND BCSC have been designed to emphasize the child's development based on Piaget's discoveries. The main objective of these programs is to help the student to acquire basic knowledge of methods of scientific investigation and also to develop curiosity through self-initiated learning, inquiry, and discovery. Thus, he becomes a scientifically literate person based on his learning abilities and his active involvement in the learning process. Piaget postulated four different sequential stages of mental or cognitive development: sensory-motor, pre-operational, concrete operations, and formal operations stage.

At the beginning of what Piaget called the sensory motor period, from birth to 18 months, the child is unable to differentiate between self and the world around him. At the end of this period, events and objects are recognized as apart from self. Physical maturation and social and physical interactions with the environment help set the stage for later intellectual development. The preoperational stage is from two years to seven years of age; this period marks the development of thought and representation as a result of language and symbolic functions. Egocentrism, the lack of ability to reason by implication, and the inability to reflect upon thought and actions are dominant in this period.

During the concrete operations stage, from about the age of seven to eleven years, the child develops the ability to perform elementary logical operations. When faced with perceptual discrepancies, he also develops the concept of conservation and reversibility. The child's ability to apply logical thinking is limited to problems centered around concrete situations.

The last of Piaget's stages is the formal operations stage. It starts from age eleven years and continues to adulthood. During this stage the young adolescent develops hypothetical-deductive reasoning, which enables him to check systematically all possible combinations. Manipulation of variables in controlled experiments, propositioned logic, and the concept of probability are also developed.

Piaget's theory of intellectual development suggests teaching and learning practices that are in agreement with the philosophy of the new science curricula and modern science education practices, mainly, the inquiry-discovery approach through active involvement by the student and peer interaction (Nelson & Abraham, 1976). Therefore, teachers who will be educating children and will be responsible for the promotion of children's intellectual and cognitive development must have the opportunity to learn and practice the process of scientific inquiry, as well as the ability to understand their students' intellectual functioning and their styles of learning. This will be necessary in order for the teachers to be able to reflect the inquiry-discovery approach in their teaching practice. Promotion of these qualities is the responsibility of teacher-training institutions. Evidence from the literature, as indicated by

Klopfer (1980) and McKinnon and Renner (1971), suggests that even though new science innovations and programs which stress inquiry have been adopted, the practice of inquiry by the teachers and students in the classroom is still an unfulfilled promise. Klopfer (1980) put it this way:

> Some have adopted the innovative methodologies and materials that stress scientific inquiry or disciplined structure or individualized instruction, but the instructional approaches used by many teachers have hardly changed at all . . . . The grand hopes for embuing science education with a new spirit of inquiry and for making science meaningful to most children have gone largely unfulfilled. These important tasks remain to be accomplished in science education in the 1980's. (p. 1)

If the inquiry-discovery approach in teaching and learning science is an effective means of promoting critical thinking and intellectual abilities as indicated by McKinnon and Renner (1971), then teacher-training institutions must reexamine their training practices and programs to overcome the shortcomings that have proved ineffective in developing inquiry-discovery skills in their product teachers. Among such ineffective practices, as indicated by McKinnon and Renner (1971) is that in which future teachers spend four years in college learning through listening to verbal lectures, being told to verify facts and concepts, giving ready-made answers without any opportunity to experience inquiry-discovery teaching and learning, especially in their science courses. McKinnon and Renner (1971) put the blame on teacher-training institutions, especially on the teaching practices of the professors, that fail to help the future teachers teach with inquiry skills. They stated:

> Secondary and elementary teachers do not take advantage of inquiry-oriented techniques so necessary to the development of logical thought because college professors do not provide examples of inquiry-oriented teaching. (p. 1047)

A study of the understanding of science processes and their relationship to cognitive development (at the formal level), college science and mathematics, and other academic variables, among a group of prospective teachers and science majors, will be helpful in efforts to improve teacher-education programs and to prepare better quality teachers.

Need for the Study

Review of the literature indicated that many studies carried out by prominent researchers, such as Renner, Stafford, Coffica, Kellogg, and Weber (1973), Johnson (1970), Raun and Butts (1967), and Scott, suggested that the inquiry-discovery approach in teaching and learning science is an effective means for promoting intellectual ability and scientific literacy among students, especially at elementary and secondary levels.

Renner and his associates (1973) investigated the effect of inquiry-discovery orientation to a project (S.C.I.S.) on students' ability to function with the processes of science, intellectual development, and achievement in math, reading, and social science. The authors found that students who studied S.C.I.S were better observors, classifiers, measurerers, experimenters, interpreters, and predictors than those students who studied science through a textbook approach. They also found that the inquiry-discovery approach through the S.C.I.S curriculum enhances intellectual development of the children, and helps them utilize their higher level of thought more effectively. Renner stated:

> We have demonstrated that the S.C.I.S. program promotes scientific literacy and intellectual development. . . . Apparently, children who have had an inquiry experience tend to utilize the higher powers of thinking more effectively than those who have not experienced inquiry. (p. 313)

Johnson (1970) compared a group of disadvantaged third-grade students exposed to lessons adapted from Science: A Process Approach (S.A.P.A.) and Elementary Science Study (E.S.S.) with a control group who had not had these same experiences. Johnson found that even though both groups gained in their IQs, students who had been exposed to S.A.P.A. gained significantly more. She concluded that the process approach did help the disadvantaged students to develop rational thinking.

Raun and Butts (1967) studied the effect of an inquiry-and-involvement type of curriculum on fourth, fifth, and sixth-graders' cognitive and affective behaviors. They concluded that

> The evidence indicates that performance in selected strategies of inquiry is correlated with those behavior

> factors associated with intelligence, divergent thinking, attending, science recall, reading and attitudinal perceptions of the potency of science. (p. 265)

Scott (1970) in a three-year exploratory study, tried to answer the following questions:

> Would an inquiry program have a continuing effect on children's behavior after the novelty of the situations had passed?

and

> Would the verbal behavioral changes in inquiry children in a three-year study be traceable to the elements of the strategy emphasized during this program?

Scott concluded:

> The inquiry strategy appears to have had a continuing effect on the verbal behavior of this group of children over the three-year testing period. The children exposed to the technique changed in several measurable ways: verbal fluency and flexibility were increased, attention to detail became more acute, inferences as to invisible attribute showed a strong trend away from emotional and locational responses, and toward the inherent classificatory attributes, and each of these changes can reasonably be traced to a specific emphasis of the inquiry strategy used in this program. (p. 101)

Teachers apparently practice little of the inquiry-discovery process in their classroom teaching, for there is ample evidence in the literature that many investigators have concluded that memorization of facts and concepts through lectures and verbal techniques is dominant over the inquiry-discovery approach. Brandwein (1969) observed 1,100 classrooms and arrived at the following conclusions:

> I found the words inquiry and process . . . being espoused all over the land, but let me give you my data: 90 percent of the teachers in the eleventh and

> twelfth grades lectured 90 percent of the time; 80 percent of the teachers in the tenth and eleventh grades lectured 80 percent of the time. They were all teaching through "inquiry." We defrauded ourselves . . . by using new words. (Cited by Unruh & Alexander, 1974, p. 3)

Gruber (1963) found that only 25 percent of those teachers attending the National Science Foundation Institute expressed their interest in inquiry-oriented science teaching. Studying the areas in which elementary school teachers need and desire help to improve their science-teaching practices, Moore and Blankenship (1977) concluded that elementary teachers need help in

> . . . providing realistic experience, developing basic skills, developing understanding of the relationship between science and society, and training in science teaching methodology. (p. 344)

Leonard (1969), investigating the effect of science-teaching method courses, found that student teachers had a limited science-process understanding, and few classrooms featured activities that related to the science processes in their teaching practices. He recommended that

> . . . prospective teachers should be required to take an entire semester course dealing with scientific method and process in science. (p. 372)

Assuming that the way prospective teachers have been trained in college is the determinant factor in the way they will teach, Sund and Trowbridge (1973) and McKinnon and Renner (1971) indicated that the inadequacy in preparing prospective science teachers by teaching them science through verbal lectures and cookbook-type labs without research experience resulted in having the quality of teachers who emphasize memorization of facts and terms through verbal lectures and demonstrations, mistakenly assuming that telling is teaching, while real and effective teaching is more than telling and talking. The inadequacy of teacher preparation, which gave us a majority of teachers who failed to implement inquiry-discovery in their teaching as indicated above, has to be investigated and reexamined in order to have valuable information on which teacher education classes can be improved. Investigating science-process understanding and its relationship to logical thinking at the formal level--college science and mathematics, high school science, S.A.T. scores--among groups of prospective teachers and college science majors will be helpful in improving teacher education.

Several studies in the literature investigated the effect of training and instruction in science processes on college students' and prospective teachers' achievement, understanding, and proficiency in using these skills. Jaus (1975) investigated the effectiveness of integrated, science-process skills instruction on prospective teachers' achievement of these skills, selection of instructional objectives related to process skills, writing of instructional objectives and learning activities dealing with process skills in their lesson plans, and attitudes toward using these skills in their teaching. He concluded that prospective elementary teachers' science-process skills achievement can be improved through training. He also found that training in process skills led prospective teachers "to select and write significantly more instructional objectives designed to teach these skills to children than do their untrained peers" (Jaus, 1975, p. 445). Among Jaus' findings was the implication that ". . . preservice elementary teachers receive little integrated science process skills instruction in their high school or college science-content courses" (p. 445).

Campbell and Okey (1977) used an experimental and control-group technique to examine the effect of instruction in process skills as prospective teachers' process achievement, process objective selection, and use of such process objectives and activities in their teaching plans. They found that treatment groups who studied self-instruction programs on process skills achieved significantly higher process skills on process measures, selected significantly more process objectives, and used more process-skills activities in their teaching plans. Campbell and Okey's findings and conclusions support those of Jaus (1975). They concluded that ". . . prospective teachers may not acquire science processes in science courses" (p. 233).

Speaking about prospective teachers entering colleges with deficiencies in science processes and their application, and that college science courses did not help in that direction, Nordland and Devito (1974) put it this way: "Unfortunately, upon the completion of 15 semester hours of university science courses, most students still have the same deficiencies" (p. 384). While Cotten, Evans, and Tseng (1978) found that "written inquiry model" is an effective means to alter prospective teacher behavior toward inquiry, in their conclusions based on corollary data collected in their study, they wrote:

> This study shows a high correlation between the completion of advanced undergraduate science hours and process skill proficiency. (p. 195)

Gabel and Rubba (1980) found that physics students gain more proficiency in process-skill training than prospective teachers, but prospective teachers gain a more positive attitude toward science.

It should be noted that while Jaus (1975) and Campbell and Okey (1977) suggested that proficiency in science process can be increased by process training, they also indicated, with support of Nordland and Devito (1974), that high school and college science courses are not effective in promoting these skills. On the other hand, Cotten et al. (1978) found that advanced undergraduate science courses correlate highly with process proficiency. With the Gabel and Rubba (1980) finding that only physics students gain in process training, we are led to conclude that more information about the effect of college and high school science experiences on process understanding and proficiency is needed.

Studying the effect of a one-semester course in physical science on cognitive development of prospective elementary teachers, Nolan (1979) found no significant change in prospective teachers' cognitive levels as a result of this treatment. Kolodiy (1975), investigating whether or not cognitive level of high school students has changed from high school through college as a result of college freshman introductory physics and mathematics courses, concluded that "college science education does not raise cognitive levels" (p. 22). He also concluded that achievement on Piaget-type tasks was correlated significantly to S.A.T. and mathematics scores. Blake and Nordland (1978) compared the effectiveness of one semester's instruction in science and mathematics through inquiry approach to an expository approach upon cognitive growth of freshman college students. Blake's conclusion was that both inquiry and expository approach resulted in cognitive growth, and inquiry-based methodology is no better than the expository approach in promoting cognitive development.

Among the researchers, the contradictory finding about the effect of college science on cognitive ability is evident. While Nolan (1979) and Holliday (1975) found that college science did not affect cognitive development, Blake and Nordland (1978) found that expository approach in college science teaching did affect cognitive growth the way inquiry approach did. Therefore, more information about the effect of college science on cognitive growth and its relationship to process understanding is needed.

McKinnon and Renner (1971) found that only inquiry-oriented approach in science produces cognitive growth, while Blake and Nordland (1978) found that inquiry approach is no better than expository approach in promoting cognitive ability in college students. There is a clear indication that more investigation about the relationship between the understanding of inquiry or science-process skills and logical thinking among prospective teachers and college science majors will help to clarify whether college science has any relationship to or effect on logical thinking and science-processes understanding.

Statement of the Problem

While the modern trend in science education calls for an inquiry-discovery approach in science teaching and learning to promote cognitive development and scientific literacy, the literature suggests that the majority of science teachers fail to practice inquiry in their classroom situations. Some researchers have suggested that college teacher-training practice is responsible for teacher's deficiencies in inquiry skills. While much of the previous research in science education has been devoted to the effect of inquiry on cognitive development, proficiency in inquiry skills, and attitudes toward science, little attention has been given to the factors that might affect science-process understanding among prospective teachers and college students.

The purpose of this study was to investigate the relationship between science-process understanding as measured by the Test of Science Processes (T.O.S.P.) and cognitive ability at the formal level as measured by the Test of Logical Thinking (T.O.L.T.), experience in science, experience in mathematics, grade point average, SAT scores, and chronological age among groups of prospective teachers and college science majors. More specifically, this study was designed to answer the following questions:

1. Which of the following variables--cognitive ability, high school and college science experience, college mathematics experience, college grade point average, SAT scores, and age--correlated most frequently with and was useful in explaining science-process understanding among prospective teachers and college science majors?

2. Is there any relationship between science-process achievement and cognitive ability among prospective teachers and college science majors?

3. Is there any significant difference between prospective teachers and college science majors as to their science-process achievement and cognitive ability?

4. Does college-science experience have an effect on science-process understanding among prospective teachers and college science majors?

Summary of Procedures

Ninety-three prospective teachers and science majors at the University of North Carolina at Greensboro agreed to participate in this study. A Test of Science Process devised by Tannenbaum (1971) and a Test of Logical Thinking by Capie and Tobin (1980) were administered to all subjects who agreed to participate. After permission was granted from the School of Education's Human Subjects Committee, the tests were administered to assess the students' science-process understanding and logical-thinking abilities.

Data on experience in science and mathematics, grade point average, chronological age, and SAT scores of the subjects were collected from students' records (with the students' permission) through the university academic records. After all needed data were obtained, statistical techniques--ANOVA, Pearson Product Moment Correlation and regression analysis--were used to analyze the data through the university computer system, using SAS computer package (Helwig & Council, 1979). All hypotheses were tested at the .05 alpha-level for statistical significance.

Limitations and Assumptions of the Study

Limitations

The following limitations must be considered when examining the findings and conclusions of this study.

1. The study was limited to prospective elementary teachers and a group of science majors enrolled at the University of North Carolina at Greensboro.

2. Because some of the science majors chose not to participate and only this specific group could be used, the sample size of the science majors was small.

3. There may be other variables that contribute to the subjects' science-process achievement for which this study did not account.

4. Some difficulties arose due to the fact that pictures on some TOSP items were not clear enough.

Assumptions

1. This study has assumed that data on grade point average, SAT scores, age, college and high school science, and college mathematics are accurate as they appear in the university records.

2. This study also assumed that the TOSP and the TOLT are useful and accurate measures of science-process understanding and logical thinking of the subjects.

3. It is assumed that a high level of science process understanding and high cognitive abilities are necessary ingredients for effective teaching.

The Study Overview

This chapter provides an introduction to the problem with some background information related to the need for the study. A statement of the problem including the main questions investigated by the study, a summary of procedures, the research design, and limitations of the study are also presented.

The second chapter will deal with the review of the literature which will include research and literature related to science-process understanding and logical thinking among college students and prospective teachers, research findings, and related literature. Other variables will be discussed.

Chapter III will include a complete discussion of the research design and procedures, statement of hypotheses, explanation of terminology, description of research instrument used in the study, and data analysis procedures. Results of the study and data analyses will be presented in full detail in Chapter IV. Chapter V will include the findings, conclusions, and recommendations appropriate to this study.

CHAPTER II

REVIEW OF THE LITERATURE

Research Related to Science Processes

The Emergence of the Inquiry-Discovery Approach in Science Education

The reform movement of the sixties and seventies, which stressed the inquiry-discovery approach in education, came as a response to the pressing and challenging problems that had been created by the space race and exploration advancement of science and technology in almost every field of life. This scientific and technological development, which is still accelerating, has created a new society dependent upon science and technology. This modern lifestyle and its emerging social, economic, and ecological demands have created a need for more scientific literacy. However, the educational process in general, and in science education in particular, was not up to the challenge. While scientists were practicing real science through methods of investigation and developing technology in response to the needs of life and society, teachers and students were involved in the fruitless process of teaching and learning science through memorization and recitation of ready-made facts and theories.

Referring to the gap that exists between science as practiced by professional scientists and the way it is practiced by teachers and students in schools, Kahle (1979) stated:

> One root of the problem was identified as the failure of science teaching to stay abreast of scientific progress; our students were still classifying leaves and wild flowers, memorizing the periodic table, and reciting the laws of mechanics. We were not preparing them to be scientists; rather we were teaching them about science. (p. 19)

Addressing the same issues, Bybee (1977) stated that "prior to the Reform Movement of the 1960's science curricula and instruction simply had not kept up with the changes in science and technology" (p. 92).

Efforts by many significant figures in science, psychology, and education reflected an emerging new perception of science teaching and learning and the construction of a new model in science education. Emphasis on the inquiry-discovery approach, as well as knowledge of and attitudes toward science, was established as one of the main objectives in science education. Achieving scientific literacy was the biggest hope of science education's new trend to meet both individual and social needs. A scientifically literate person can cope with and adapt to a rapidly changing technological society through his ability to solve personal and social problems and to promote and direct social change.

According to Carin and Sund (1980, p. 40), the scientifically literate person that the new science education trend seeks to develop is characterized by the following:

1. Uses scientific concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment.

2. Understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories.

3. Distinguishes between scientific evidence and personal opinion.

4. Identifies the relationship between facts and theory.

5. Recognizes the limitations as well as the usefulness of science and technology in advancing human welfare.

6. Understands the interrelationships between science, technology, and other facets of society, including social and economic development.

7. Recognizes the human origin of science and understanding that scientific knowledge is tentative, subject to change as evidence accumulates.

8. Has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others.

9. Has a richer and more exciting view of the world as a result of his science education.

10. Has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation, and its excitement of inquiry.

11. Continues to inquire and increase his scientific knowledge throughout his life.

Securing the balance between conceptual schemes, science concepts, and science process in science curriculum oriented toward inquiry and discovery will help promote these qualities in students. Piaget's effort to understand the cognitive process and how the logical thinking process develops in the child, and Bruner's work in learning through discovery helped set the stage for the inquiry-discovery approach to be implemented in science curricula and instruction (Carin & Sund, 1980). This may be witnessed in the development of many science curriculum projects which stress the inquiry approach in elementary, secondary, and college-level education. Nolan (1979) wrote:

> Under the influence of such leaders as Jerome Bruner and Jean Piaget, educators began to emphasize the process of science and the personal development of the students, in their pedagogical organizations. Much of this effort has come together under the title of "inquiry" education. (p. 9)

The establishment of inquiry-oriented curricula and its application was one of the most exciting and promising things that had ever happened in the field of science education. Accordingly, many believed that the mere creation of new programs in science education would fulfill the inquiry-discovery practice and the scientific literacy objective would be achieved. However, data from the field related to the effectiveness of this new approach revealed that creating a new inquiry-discovery approach curriculum was not enough to have inquiry teaching and learning practiced in the classroom. Teacher training for those who would teach or supervise this new curriculum added a new dimension to the problem. A new training program for those who were already on the job, as well as for those who would teach in the future became a necessity in order for the new science education approach to be successfully implemented. Rutherford (1971) put it this way:

> Sooner or later each secondary school curriculum development project has come to realize, sometimes to its chagrin, that curriculum development alone is not enough. No matter how carefully designed the emerging course, no matter how capable it is in principles of serving the needs of students and indeed, no matter how well the course seems to work when tried out experimentally, the unhappy truth is that in general practice the course simply not work as the designer intended unless the generality of teachers who used it are prepared to make it work. (p. 555)

Therefore, some effort and time would have to be devoted to in-service and pre-service training in subject matter, philosophy, and a teaching style suitable to these programs. But for one reason or another, these efforts unfortunately did not fulfill the promise of the inquiry-discovery practice by the teachers in the teaching and learning process. The need for further efforts to improve teacher quality, through research and continuous training, was obvious.

The Status of Inquiry-Discovery Practice by Teachers

The reform movement in science education resulted in the development of an inquiry-discovery orientation in the science curriculum with more student involvement through the inquiry process and with less emphasis on memorization of facts and concepts. However, a number of challenging and complex problems arose in its implementation. One of these was to find teachers of quality who accepted the philosophy of the new science education trend and had the skills required to practice the inquiry-discovery approach in their teaching. It was obvious that the understanding of science concepts and processes by the teachers was essential to the success of the new programs. Carry and Stauss (1968) stated that "if a 'modern' approach to science teaching that reflects the nature of science is to be utilized, the teacher must be prepared accordingly" (p. 359). For the past two decades, many efforts have been devoted to the improvement of both teacher qualities and educational facilities in an effort to achieve scientific literacy and inquiry skills through the new programs among students. But research evidence suggested that the hope for improvement, in spite of all efforts, was still an unfulfilled promise. Welch (1981), in examining several studies related to the actual status of science education relevant to inquiry, concluded:

> The education leaders expected the new curricula and the revised teacher preparation programs to have demonstrable impact on classroom practice and student achievement. However, the results of our study show that these expectations are far from being realized. (p. 41)

Many researchers suggested that in one way or another, the lack of inquiry-discovery practice by teachers was one of the main contributing factors to the unfulfilled inquiry promise in science education. Paul F. Brandwein (1968) observed 1001 classrooms; he concluded that the majority of teachers claimed to teach through inquiry, when in fact more than 80 percent of them were talking most of the time. Gruber (1963) found that only 25% of those teachers attending the National Science Foundation Institute course expressed an interest in inquiry-oriented science teaching. Leonard (1969), investigating the effect of the science-teaching method course, found that student teachers had a limited understanding of science process and had few classroom activities related to the science process in their teaching practice. He recommended that prospective teachers should spend one semester studying scientific method and science processes. Hurd (1971) stated that observation from classroom practice by teachers suggested that as many as 50 percent of the teachers who taught the innovative programs failed according to the program's specified goals. Klopfer (1980), in expressing his view about the lack of inquiry practiced by teachers, mentioned that in spite of claims by many that they utilized scientific inquiry in their instruction, in real practice their instructional approach had hardly changed. This evidence in the literature related to the lack of inquiry practice in science education leads us to examine some of the factors behind this unhappy truth.

Factors such as the lack of educational facilities, class size, time allocated for science teaching and the recognized effort needed by all involved in this approach to science education--all contributed to the problem.

Possibly the treatest contributing factors were both the nature of the teacher and the nature of the in-service and pre-service teacher-training programs. George and Nelson (1971), addressing the effect of the type of teacher and the effectiveness of some in-service training programs, indicated that

> Observation of on-the-job performance while teaching science suggests that not all persons benefited from in-service work when that training involved different types of teaching behaviors. The literature suggests two possible reasons:
>
> 1. persons involved in the in-service training may not be adaptable enough in order to assimilate or accommodate the required behavior, and
>
> 2. the type of training employed may effect positively or negatively those who think the newer teaching model is "good or bad." (p. 168)

Changing the in-service teaching style toward the inquiry method required real involvement by the teacher. This method included that teachers be put in a situation where they could have a real opportunity to state a problem and carry out the procedure for its solution as a way of learning concepts and facts of science. To taste the joy of inquiry, teachers must also be given the opportunity to learn how to design an inquiry-oriented lesson and to carry it out in a situation where they can be helped by feedback and objective evaluation. However, gathering a group of in-service teachers and lecturing them about inquiry and science would not help change their teaching styles to any great extent. Bybee (1974) put it this way:

> Teachers attended institutes, furthered their knowledge, obtained new science kits, and returned to their classes with the same teaching style. The point is: inquiry is something people do; it is not the curriculum or something that is intellectualized. (p. 9)

The lack of adequate inquiry training in pre-service teacher-training institutions is also cited by many as part of the problem. Sund and Trowbridge (1973) and McKinnon and Renner (1971) explained that prospective teachers spent most of their college years learning the product of science through lectures with little or no emphasis upon the scientific process. Therefore, prospective teachers have not had an opportunity to devise an experiment or engage in a real problem-solving situation. All they have learned is that teaching is telling, and this is what they do when they assume their teaching responsibilities. In a review of eleven in-depth case studies in science education prepared by the Center for Instructional Research and Curriculum Evaluation at the University of Illinois, Stake and Easley (1978) and Welch and others (1981) indicated that inquiry approach difficulties, difficulties in getting equipment and supplies, and teacher claims that inquiry approach might not work for most of the students and that inquiry is difficult for those who are not very bright were some of the reservations held by teachers in relation to inquiry teaching, all of which contributed to the lack of inquiry practice in their teaching. Welch and others (1981) concluded that the traditional view held by teachers and parents that the science education objective was to prepare the students for the next educational level, and also lack of equipment and poor teacher preparation in inquiry all combined to promote traditional teaching styles in most of the classrooms.

Having examined these findings in the literature which indicated that the lack of inquiry-discovery practice in science education has been contributed to by many factors as stated, the writer feels strongly that teacher training, especially in pre-service training, can make a difference and can help improve the quality of prospective teachers. To become an inquiry-oriented future teacher, who gives the opportunity to learn science through real investigation in real problem-solving situations, may not be an easy process given the factors of time, effort, equipment, and the pressure on the professor to cover a certain amount of subject matter in a limited time period. However, the writer feels that if those involved in college science teaching can see the importance of the inquiry approach for the prospective teachers' own learning and development and for their future teaching practice, then they might be able to overcome the obstacle and to introduce inquiry in their college science teaching.

Research Related to Science Process Among Prospective Teachers and College Students

Many investigators have addressed themselves to the effect of science-process instruction on prospective teachers', in-service teachers', and college students' science process achievement, attitude, and skills' practice. Jaus (1975) investigated the effects of integrated science-process instruction on 90 prospective elementary teachers' achievement of science-process skills, selection of science-process skill instructional objectives, writing of science-process skills related to learning objectives and activities in lesson plans, and the attitude toward using these skills in the elementary classroom. The 90 prospective teachers enrolled in three elementary science method courses. They were assigned randomly to three different instructional treatments. One class received science-process instruction through self-instructional pamphlets; the second class used the same pamphlets plus a persuasive communication; and the third class received placebo instruction. Jaus found that prospective teachers who received science process instruction through pamphlets and improved their science-process achievement selected and wrote significantly more instructional objectives designed to be used in their teaching plans than the untrained group did. But no change in attitude as a result of instruction had been detected and no significant relationship between prospective teachers' open- or close-mindedness and the five dependent variables had been found. Jaus concluded that science-process achievement could be improved through self-instructional materials, and that prospective teachers had little science-process skill instruction in their college or high school science courses. Jaus' research design is somewhat questionable because of the lack of pre- and posttest technique. There is a possibility than an initial difference existed between the controlled and the experimental group. Comparisons of the pretest group with the posttest group would have aided the judging of significant differences between the two groups on the dependent measures.

Campbell and Okey (1977) also examined the effects of teaching science process skills through self-instructional programs with prospective teachers. They examined the effects of teaching science process skills on science process achievement, process objective selection for the science unit, use of science process objectives and activities in lesson plans and attitudes toward process skills and relationships. Campbell and Okey's findings supported Jaus' (1975) findings that prospective teachers' science-process knowledge could significantly be improved through instruction and that prospective teachers sèlected more process-skill objectives for science units. But while Jaus (1975) found that trained prospective teachers wrote more science-process objectives and had more learning activities in their lesson plans, Campbell and Okey found that trained prospective teachers included significantly more process-skill activities in their lesson plans. However, they did not include more process objectives in their lesson plans than did the control group as indicated by Jaus (1975). Another point of disagreement or conflict was that while Jaus found no relationship between prospective teachers' open- or close-mindedness and the five dependent variables investigated, Campbell and Okey found that there was a significant positive correlation between open-mindedness and use of the basic science process skills in lesson plans. both studies concluded that training prospective teachers in science processes would not change their attitudes toward the use of these science-process skills. The implication of Jaus (1975) and Campbell and Okey (1977) that prospective teachers and college students might not acquire science-process skills was an alarming conclusion that must be taken seriously by both college science teachers and teacher-training institutions. This is especially significant when science processes by prospective teachers were improved in a short period of time, and this improvement was accompanied by better performance by the prospective teachers in their teaching planning and teaching practice. While the finding of both studies was that the attitude of the experimental group toward science-process use was not significant, it is understandable that attitude change is a complex process and difficult to measure in such short periods of time. Therefore, if attitude toward science and science processes is an important factor in science-process understanding and its practice by prospective teachers, the writer feels that the practice of science processes in science content courses and in professional science education courses is essential throughout the college years, in order to ensure the development of a positive attitude toward science and science-process understanding and its use.

Pappelis, Pohlman, and Pappelis (1977, 1980) examined the effect of the Science--A Process Approach (S-APA) type of process activities on college students' science-process achievement. Pappelis et al. (1980) used a specially designed course for premedical and predental students to improve their science-process achievement and their problem-solving abilities. The course used the sequence and exercises of the S-APA program with a modified context for use with medically oriented students in a pre-post-test type of design with no control group. Thirty-eight students took the course during five consecutive semesters. Each semester the group enrolled was pretested with the Test of Science Process (TOSP) and then posttested with the same TOSP after completion of the course. Even though the course emphasized science processes such as observation, comparison, classification, quantification, and measurement, more attention was given to integrated science processes such as controlling variables, formulating hypotheses, defining operationally, interpretation, and experimentation. Pappelis et al. found that students exposed to the science process course gained significantly from scores of 77.2 out of a possible 96 on their pretest to a score of 80.4 on their posttest total score. The students made more significant improvements in skills of measuring, quantifying, and inferring subscales with the acknowledgment that the use of a control group would have been more desirable. The researchers concluded:

> College students found to be deficient in science process skills could benefit from instruction in those skills . . . and that college science teachers should not blithely assume that students are capable of formal operativity or of performing even the most basic science process skills, regardless of whether the students are science or nonscience majors. (pp. 28-29)

Pohlman and Pappelis (1977) developed an elective course to be used by the nonscience majors, especially elementary school teacher majors. The material and the activities were drawn directly from the S-APA curriculum after 84 nonscience major students completed the course. The researchers concluded that S-APA program materials and exercises can be used to improve nonscience majors' process skills. This finding supports those of Pappelis et al.(1980). Pohlman and Pappelis also suggested that college science teaching had to introduce activity-based rather than lecture-based programs.

The question of what type of lab activities might affect college students' science-process understanding was raised by Cannon (1975) and Serlin (1976). Comparing the effects of an open student-directed lab to a highly structured traditional lab in 80 general education physical science courses, students' interest and understanding of the science process was carried by Cannon (1975). The open-lab group was encouraged to use, to develop, and to direct their own lab activities. The other group followed a traditionally structured cookbook-type lab. Using the Welch process of science inventory and interest assessment scales as pre- and posttests, Cannon found there was no significant difference between the two labs' approaches with respect to the understanding of science process and interest. Cannon concluded that the varied degree of freedom in the lab did not change students' understanding of the science process. It is obvious that the degree of freedom given by turning the student loose in the lab while his research and investigative abilities are limited might not work without training. If this freedom is to be effective, some kind of guidance and some type of training in the process of science are required before the student can choose difficult lab activities on his own and then carry them out in a manner that will improve both his science-process skills and investigative ability.

In an experiment with a controlled group design, Serlin (1976) investigated the effect of a discovery laboratory on the science process and on the problem-solving abilities of 67, third-quarter calculus students in an independent setting. The experimental group attended the discovery lab which used content, format, and scheduling based on the following:

1. activity matched to the learner's cognitive level;
2. use of an advance organizer;
3. guidance in describing the nature of science as discovery activities.

Serlin found this type of lab arrangement was significantly effective in improving the students' science-process skills. Serlin also concluded that evidence suggested previous physics courses and traditional physics laboratories were not effective to improve students' process skills. The finding related to the effect of the type of lab arrangement is conflicting in its finding and its conclusion. While Cannon (1975) found that open, unstructured lab is not more effective than traditional lab on the science-process understanding, Spears and Dean (1977) found that the traditionally structured lab is better than the inquiry lab. At the same time, Serlin (1976) found that open lab, which matched the learner's level of thinking to activities and to use of an advanced organizer, proved to be more effective at science-process achievement among students than did the traditional lab. These differing and conflicting findings raise more questions about the effectiveness of the lab practice on the understanding of the science process among college students.

There are some studies which are designed to assess the effectiveness of inquiry- or process-oriented science courses on the college students' cognitive growth. Blake and Nordland (1978), in a pretest/posttest experimental and control group design, assigned 97 students randomly in two groups. One group received the inquiry-based, mathematics-science teaching and the other received the expository mode of teaching. The measuring of the level of intellectual development through five Piagetian tasks as both pretest and posttest were used for both groups. Blake and Nordland found the inquiry-based, mathematics-science course for one semester did not facilitate cognitive growth any better than the parallel expository approach did. Both groups showed cognitive growth during the one semester.

In a parallel study carried out by McKinnon and Renner (1971), it was found students who were exposed to an inquiry-oriented science course exhibited significantly greater cognitive growth than did those who did not share the same experience. The finding of McKinnon and Renner, which does not agree with that of Blake and Nordland, was questioned by Ehindero (1977), which indicated that such a finding is based on a questionable assumption--whether inquiry instruction for one semester is enough to promote cognitive development from one stage to another. It also suggested that a follow-up study could have been more effective in evaluating the effectiveness of inquiry-oriented science courses.

Porterfield (1969) and Wilson (1967) found that teachers who had been exposed to the inquiry approach used more high-level cognitive thought than those who did not have a similar experience.

In a study conducted by Friot (1970), it was found that seventh-, eighth-, and ninth-grade students who had had experience with an inquiry-approach course were functioning at a higher level of logical thought than those who had not had the inquiry instruction.

Even though evidence seems to suggest the inquiry approach is effective in promoting cognitive growth, the difficulty lies in measuring cognitive thought and the complexity of the intellectual growth process itself and its gradual development over a long period of time. Both long-term and follow-up studies may be more accurate in comparing the inquiry approach with other techniques and their effect on cognitive growth.

Science Processes Among In-Service Teachers and Their Students

In-service teacher training became an essential process through which the teacher keeps up with what is new in his field and ensures his continuing professional growth in an ongoing and ever-developing context of new teaching techniques. The emerging new trend in science education and its emphasis on the inquiry-discovery approach make ongoing training for teachers a necessity if the implementation of new programs is to be successful. This is especially true for those teachers who do not have any type of training with the new process and who have not acquired a philosophy regarding this process in pre-service training.

Many efforts have been devoted to in-service teacher training through inquiry-oriented short courses and workshops. Efforts have also been devoted to the effects of such training on the teacher in terms of science process achievement, attitude, classroom practice, and their students' achievements and development.

Studies by Eaton (1974), Schmidt (1969), Porterfield (1969), and Wilson (1967) all addressed themselves to the question, what effect does inquiry-oriented training have on the teacher and his students? Eaton (1974) investigated the effect of the S.C.I.S. in-service workshop in which 23 elementary teachers taught inquiry-oriented S.C.I.S. materials on teachers' questing behavior, open- and close-mindedness, perceptions of teacher behavior, and their students' achievement in science process skills. After the treatment, Eaton compiled the results of the experimental group, who taught S.C.I.S. to their students, with a control group, who taught science via textbooks. He found that the S.C.I.S. trained teachers were more open-minded, wanted less control, used more high-level questions, and their students achieved more understanding of the science process.

Wilson (1967) designed a study to observe the practice of 30 classes of elementary children. Fifteen classes were taught science by a teacher who had been trained in the inquiry-oriented method and with materials for science teaching. The teachers of the other 15 classes did not have the same experience. Wilson found that (1) the children of inquiry-educated teachers achieved more essential science experience; (2) traditional teachers used significantly more recognition and recall questions; (3) inquiry-trained teachers used analysis and synthesis-type questions more often than traditional teachers; and (4) while inquiry-educated teachers used more demonstrations of skill-type questions, traditional teachers used more comprehension-type questions. The findings of Eaton (1975) and Wilson (1967) seemed to suggest that in-service teachers trained in inquiry methods and materials improved their teaching practice by giving opportunity to their students to be more involved, and by encouraging pupils to investigate and search for their own answers to problems. This finding is supported by Barnett's (1976) study in which he studied the effect of a workshop which used the Science--A

Process Approach curriculum, materials, and equipment on a group of elementary teachers and their students. Barnett concluded that workshops which include teachers in active participation through the science process will be able to transfer inquiry-oriented activities and experiences to their classroom situations and their students' science-process understanding, and their equipment use will be improved.

Review and examination of Wilson's (1967) study and other studies with similar findings (Renner & Stafford, 1970), raises the question of whether the detected difference between the inquiry-trained and the traditional teacher is related to the materials which the students have, or is it really the inquiry-educated teacher that makes a difference? A study by Schmidt (1969) was designed to explore that possibility. Schmidt's study examined the changing teaching style of 16 elementary school teachers of both social studies and science. After they completed a summer workshop in new science which compared the teaching patterns of these groups of teachers while they were teaching science and social studies, both before and after the workshop, Schmidt found that following the workshop, teachers used the inquiry-centered materials in science classes, and at the same time, they were using traditional materials with social studies classes. Based on these study data, the teachers changed their teaching patterns in science as well as in social studies. Therefore, the changing of the instructional pattern from traditional to inquiry is due to inquiry training and not to the students' materials.

In another study (Cotten et al., 1978), 70 elementary teachers were trained in inquiry-investigative activities through a written model. Comparing the experimental group with a control group who did not have such experience, Cotten found that the experimental group gained a significant increase over the control group in observing, predicting, and identifying variables, and in classifying and controlling variables. The experimental group also asked more open questions and used less lecture activities. Students of these teachers showed significantly more positive attitudes toward science instruction and performed more nonverbal activities as well as more peer interaction. Based on their data, Cotten et al. found that proficiency in science-process skills correlates highly with the number of advanced science hours completed. Cotten et al. (1978) concluded that "the success of the written model in effecting significant change toward inquiry behavior has been well documented in this study" (p. 194).

Based on the findings and conclusions of the studies that have been examined which related to the effect of in-service teacher training on teachers and their students, it is evident that teachers trained in inquiry-oriented activities will become more inquiry-oriented teachers as their inquiry-process understanding and practice improve. These improved inquiry qualities help the teachers to pass these experiences on to their students through their classroom practices. This finding is supported by other studies such as those conducted by Wall (1975), Swami (1975), and Porterfield (1969). However, Wall's (1975) study found that the inquiry skills of students who are taught by inquiry-trained teachers are no better than the inquiry skills of those students whose teachers did not have such training.

Eaton (1974) and Barnett (1976) found that science-process understanding and use were significantly enhanced among students of inquiry-trained teachers. In spite of this disagreement, the majority of studies support the assumptions that the students of inquiry-trained teachers become more involved, receive more essential science experience, become active investigators, and interact more among themselves. Teacher-training institutions have to consider this finding and its effectiveness in improving the teaching and the learning process.

Renner and Stafford (1970), commenting on the finding of several of the above described studies put it this way:

> Based upon the data from the research studies just described, we hypothesize that specialized educational experience in inquiry-centered science teaching encourages a teacher to become sensitive to children, functionally aware of the purpose of education, and

> equipped to lead children to learn how to learn in all subject areas. In short, we hypothesize that inquiry-centered experience in science education prepares a teacher to teach all subjects from an inquiry point of view. While the foregoing statement is a hypothesis, the data presented have suggested that the profession cannot afford to leave it untested. (p. 57)

Science Processes Among Students Below College Level

The effect of the inquiry-discovery approach in teaching and learning science on student intellectual abilities and scientific literacy at the elementary level has been investigated by many researchers. Renner et al. (1973) investigated the effect of an inquiry-discovery (SCIS) project on a group of elementary school students and their functioning with the processes of science, intellectual development, and achievement in mathematics, reading and social science. Renner and his associates found that students who studied science through SCIS proved to be better observers, classifiers, measurers, experimenters, interpreters, and predictors, than those children who studied science through textbook approach. Renner also found that the inquiry-discovery approach through the SCIS project enhanced intellectual development of the children, and helped them utilize their higher level of thought more effectively. Renner concluded that an inquiry-oriented curriculum such as SCIS was superior to a textbook program in aiding development. This finding should be examined and considered carefully by those who are now teaching science as well as prospective teachers who are going to teach it to the children.

Johnson (1970) compared groups of disadvantaged third-grade students exposed to lessons adapted from Science--A Process Approach (SAPA) and Elementary Science Study (ESS) to a control group, who have not had these same experiences. Johnson found that even though both groups gained in their IQ, students who were exposed to Science--A Process Approach did gain significantly better. He concluded that the process approach did help the disadvantaged to develop rational thinking. Raun and Butts (1967) studied the effect of the inquiry and involvement type of curriculum on fourth-, fifth-, and sixth-grade cognitive and effective behavior. Raun and Butts found that "performance in selected strategies of inquiry is correlated with those behavior factors associated with intelligence, divergent thinking, attending, science recall, reading and attitudinal perception of the potency of science" (p. 265). Scott (1970) in a three-year exploratory study, tried to investigate the inquiry approach continuing effect on children's behavior, past the novelty of the situation. He also examined the effect of inquiry program on verbal behavioral changes and whether or not this behavior change can be traced to the elements of the emphasized strategy in the program. Scott concluded:

> The inquiry strategy appears to have had a continuing effect on the verbal behavior of this group of children. Over the three years testing period, the children exposed to the technique changed in several measurable ways: verbal fluency and flexibility were increased, attention to detail became more acute, inferences as to invisible attributes showed a strong trend away from emotional and locational response, and toward the inherent classificatory attributes, and each of these changes can reasonably be traced to a specific emphasis of the inquiry strategy used in this program. (p. 95).

This study was well designed for tracing the effect of inquiry strategies on students for a reasonable amount of time, and supported the findings of those previously examined studies that inquiry approach and utilization of inquiry strategies in teaching and learning science are an effective approach for promoting students' ability to understand and use science processes suitable to their level of ability. At the same time these processes are essential in promoting students' cognitive abilities and their becoming scientifically literate persons. The effect of inquiry-oriented science programs and teachers' experience background and attitude toward science on secondary-school students' science-process achievement and critical thinking was investigated by Peterson (1976), Hillis (1975), Wright (1976), Pettus and Haley (1980), and Batten (1976). Peterson (1976) designed a study to investigate the effect of inquiry training on high school students' abilities to do scientific investigation. A sample of 675 high school students were divided into three groups: a control group which completed nine weeks of project physics and verbal instruction in science inquiry; a second group which was taught science through a combination of project physics and verbal instruction; and a third group which completed a science-inquiry training program. Analysis of posttest science-inquiry scores showed that the science-inquiry group significantly out-performed the other two groups on almost all the test items including science-processes identification and relationships. Peterson concluded that instruction in scientific-inquiry skills and information as well as concrete materials with abstract verbal instruction was of functionally significant value for the student.

Examining the relationship between teacher attitude toward inquiry teaching, degree of science-inquiry activities in the classroom, and students' critical thinking and attitudes toward the science curriculum, Hillis (1975) found that "Teachers' attitude toward inquiry teaching strategies is a poor predictor of student critical thinking skills, attitudes toward the science curriculum" (p. 805. He found that a science classroom activities checklist is a better predictor of students' variability. Hillis concluded that inquiry-oriented science students have a higher critical thinking skill, viewed science as tentative, and hold an attitude toward science teachers and science classes more favorable than do those students who are in a less inquiry-oriented, physical science class. Peterson's (1976) and Hillis' (1975) findings seem to suggest that inquiry-oriented science activities help the student to improve his inquiry skills and critical thinking better than non-inquiry-oriented science classes. Wright (1976) found that there was no significant difference on science-process skill achievement between seventh-grade students who studied an SCIS inquiry-oriented science curriculum and those who had studied a traditionally oriented science curriculum. It is also interesting to note that while Hillis (1975) found that inquiry-oriented groups have more favorable attitudes toward the science teacher and science classes, Wright (1976) found that non-inquiry-oriented students have an attitude toward science more closely related to the attitude of professional scientists. It is evident that some conflicting findings have been detected, but teachers' quality, the type of equipment, and differences in measurement instruments used in these studies might be contributing factors to these differences.

Pettus and Haley (1980) and Batten (1976) addressed themselves to the question of what factors might be associated with and be able to predict science process skills and use among high school students? Pettus and Haley's (1980) study was designed to investigate the relationship between the science-process skill level of high school students and their sex, age, grade level, number of completed science courses, and interest in science careers. After the data for the five independent variables and the dependent variable test of science processes were gathered from a sample of 505 ninth- to twelfth-grade students, Pettus and Haley found that the numbers of science courses completed accounted for 14.75% of the total variance explained by the five independent variables on the science process test total. The number of science courses completed accounted for more of the variance on the subscores of observing, comparing, quantifying and predicting.

Their conclusion was that the relationship between overall science-process skill levels of the students and the combined effects of sex, age, grade level, interest in a science career, and number of science courses completed is significant, and that the number of science courses has the strongest relationship to the overall science-process skill performance. The grade level and age have little relationship to the overall science-process skill level, but age was related to the process of classifying and grade level was related to experimenting and inferring. Pettus and Haley indicated that science instruction quantity and quality may have been important in developing science-process skills. Batten (1976) investigated the relationships among students' ability to use science processes and their achievement on certain standardized tests and science experience aspects of their teachers' educational and instructional experience. Batten found that SCAT quantitative test scores were the significant predictor of students' ability to use science processes. Previous enrollment in eighth-grade science and in an introductory physical science course were also related to the students' ability to use science processes. Characteristics of teachers including age, sex, mathematics experience, areas of indorsement, years of NSF academic year institutes, and number of mathematics and science workshops, were significant predictors of students' use of science-processes skills and formal reasoning abilities. Padilla, Okey, and Dillashaw (1981) using a sample of middle and secondary students (N = 492), found that science processes as measured by the Test of Integrated Processes Skills (TIPS) is related to logical thinking abilities (TOLT). The studies by Pettus and Haley (1980), Batten (1976), and Padilla and Dillashaw (1981) seem to suggest that science-processes skills are related to previous science experience, aptitude, quantitative abilities (SCAT), and logical thinking abilities (TOLT) among high school students.

The overall finding of the research related to science processes below college level supports the argument that teaching and learning science through inquiry skills at the secondary and elementary level is helpful in promoting science concepts and processes as well as cognitive abilities.

Cognitive Development at the Formal Level

According to Piaget, formal-operational thought is characterized by the ability of a child to perform hypothesized, deductive, and propositional reasoning, as well as the ability to reflect on his own thinking, to understand probability, and to perform ratios and proportions. The development of such abilities helps the child to perform mental operations needed in dealing with concepts, abstractions, and theories that are required in learning many high school and college subjects, especially science. Since Piaget asserted through his observations that formal operational thought starts at eleven years of age and goes forward, many have assumed that most high school and college students are operating at the formal level (Sayre & Ball, 1975).

Research in cognitive development which used Piaget-type tests to assess the intellectual abilities among high school and college students indicated that most adolescents and young adults did not reach the formal operational stage of logical thinking as indicated by Piaget. Chiappetta (1976) reviewed several studies and stated:

> The research reviewed indicates that the majority of adolescents and young adults function at the concrete operational level and not at the formal operational level in understanding a great deal of the science subject matter taught at the secondary and college level. (p. 255)

Mallinson (1975), after reviewing several studies related to Piaget's developmental theory at the college level, concluded that Piaget's assumption that adolescents in general may perform at the formal level might not be true. In light of such findings, many more efforts have been devoted to the pursuit of a better understanding of the thought process and intellectual functioning of high school and college students. These efforts dealt mainly with the assessment of adolescents' and young adults' cognitive abilities and the relationship between cognitive development and other variables.

McKinnon and Renner (1971), Lawson and Renner (1974), Juraschek (1974), and Ehindero (1977) investigated the cognitive ability of college students, using Piaget-type tasks. These studies tried to verify the assumption that the majority of college students are able to think logically at the formal operational level.

In response to various science professors' concerns about the inability of freshman students to think logically when faced with simple problems, as well as the students' complaints about curricula inadequacy, McKinnon and Renner (1971) designed a study to assess the cognitive ability of 131 freshman college students, and to find out whether the majority of college freshmen have the mental abilities required to handle science principles in their college classes. Using five Piaget-type tasks, the researchers found that 50 percent of their college freshman subjects were concrete-operational thinkers, 25 percent were in transition to formal thinking, and only 25 percent of their subjects were at the formal-operational level of thinking. McKinnon and Renner concluded that almost 75 percent of college freshmen entering the university were either partially or completely concrete thinkers. The researchers also indicated that lack of inquiry practice in college science teaching is a factor in the lack of students' formal cognitive growth. They also indicated that inquiry-oriented science courses improved students' cognitive abilities.

In another study, Lawson and Renner (1974), using five Piaget-type tasks, assessed the developmental level of 143 freshman students randomly sampled from a private university. The researchers found that 51 percent of the sample were at the concrete-operational stage, 27 percent at the post-concrete stage, and 22 percent were at the formal stage. This study supported the findings previously examined by McKinnon and Renner (1971) that the majority of freshman college students were at the concrete-operational level. These findings raised many questions about the inability of college students to think logically. Some questioned the universality of Piaget's stages of formal thought and suggested that maybe Piaget postulated his formal-thought criteria as a result of his observations of more intelligent Swiss students. Kolodiy (1975) indicated that a mismatch exists between college students' mental ability and the content and teaching technique of college science courses.

Juraschek (1974) studied the performance of three groups of college students on three Piaget tasks. His sample consisted of 141 prospective elementary teachers, 19 secondary-school mathematics student teachers, and 11 honors calculus students. Piaget tasks used were equilibrium in the balance, quantification of probabilities, and colorless chemical liquids. The researcher found that 48 percent of the prospective teachers were formal, while 52 percent were concrete-operational. Among the mathematics student teachers, 99 percent were formal, and only one percent were concrete. The honors calculus students were all formal thinkers. The findings of this study related to prospective teachers seem to agree with previously stated data, which indicated that the majority of college students were not able to think logically. While the findings related to mathematics they seemed to suggest that the majority of mathematics students were at the formal level, in disagreement with what the literature suggested about the overall college student's cognitive ability, especially among college freshmen. However, examining this study's sampling procedure suggests that findings related to mathematics students might not be as valid as they seem to be. They could be too generalized because of sampling procedures, especially because of the small number of students included and because mathematics students are supposed to acquire logical thinking before they can be specialized in advanced mathematics. The low number of Piagetian tasks used also might be a factor contributing to the conflicting findings with other studies, which used more than three tasks.

Ehindero (1977) designed a study to assess the cognitive development of prospective teachers. He administered five Piagetian tasks to 44 prospective elementary teachers and found that 32 percent of the prospective teachers were at the concrete level, while 68 percent were at the formal level. Even though he found a greater percentage of prospective teachers who were able to think logically than Juraschek (1974) found, he indicated that formal operations among prospective teachers were not universal and that formal and concrete thinking coexisted and the applications of either were dependent on the nature of the tasks. He also concluded that cognitive development among prospective teachers is related to both college science experiences and success.

Assessment of the cognitive-development level among high school students was carried out by many investigators. Stolper (1978) using five Piagetian-type tests to assess the cognitive abilities of 129 ninth-grade students, found that 66 percent of the subjects were concrete and only ten percent were formal. He also found a moderate correlation between cognitive development and academic achievement.

Renner and Stafford (1972) administered six Piagetian tasks to 290 students in grades 10, 11, and 12. They found that 66 percent of the students were concrete thinkers, 17 percent were at the post-concrete level, and 14 percent were at the formal level of thinking. The findings of Stopler (1978) and those of Renner and Stafford (1972), which indicated the majority of high school students were concrete thinkers, were supported by findings in a study done by Nordland, Lawson, and Kahle (1974). They found that 85 percent of 506 randomly selected high school students were at the concrete stage and only 13.2 percent were at the formal-applications stage after they had administered ten Piagetian type tasks to their subjects. Karplus (1975) also found the majority of high school students aged 13 to 14 years in seven different countries were at the concrete and transition stages.

The overall findings of these studies that dealt with cognitive development of college and high school students seem to suggest that the majority of adolescents and young adults function at the concrete-operational level. This conclusion is in agreement with that of Chiappetta(1976) and with that of Mallinson (1975) in a review of a number of

Piaget's related studies. Mallinson (1975) stated, "adolescents may not generally be so formal operational as Piaget suggested" (p. 22). In another review of a group of Piaget-related studies, Chiappetta (1976) concluded:

> The ranges reported for subjects at the concrete operational level were between 77 to 83.4 percent for junior high school students, 22 to 85.8 percent for high school students, and zero to 52 percent for college students. (p. 255)

Chiappetta also indicated that while some students seem to perform at operational levels on Piagetian tasks, their performance on science abstract concepts is limited to concrete thinking. In light of these findings and the fact that most high school and college science subjects require abstract thinking, many educators expressed their concern about the adequacy of content and technique of science teaching as a means for cognitive development.

Renner and Lawson (1975) indicated:

> Lack of development of intellectual capabilities can be traced to inappropriate instructional strategies and materials at the secondary and college levels. (p. 89)

In order for science teaching and learning to be able to promote cognitive development, the clear implication is that there should be a match of subject content and students' mental abilities, and that the transmission of facts and concepts being memorized by the student as major teaching objectives should be replaced by the inquiry-discovery practice to promote cognitive ability (McKinnon & Renner, 1971).

Summary

The review of the literature presented in this chapter revealed the following points:

1. Emphasis is being placed on the inquiry-discovery approach as a means of teaching and learning science concepts and processes, with the hope that the realization of this approach in science education will promote students' cognitive ability and scientific literacy.

2. In spite of efforts through new and innovative curricula, and new and more equipment and facilities, evidence from the field suggests that the goal of inquiry-discovery practice is far from being reached. The lack of well-trained teachers who have the will and inquiry skills to practice inquiry in the classroom was one of the main obstacles toward the realization of inquiry-discovery practice in science education.

3. While college students and prospective teachers might not acquire science processes and problem-solving skills through their college training, training in these skills in specially designed courses proves to be effective. Prospective and in-service teachers who receive training in these skills prove to be more effective in their teaching practice than those who did not receive such training.

4. There was a conflict and inconclusive evidence related to the effect of inquiry-oriented college science courses on college students' cognitive abilities. However,

the literature suggested that the effect of inquiry-oriented science courses on students below college level is more evident.

5. While some efforts have been devoted to investigating the relationship between science processes achievement and other variables such as cognitive abilities, science experience, sex, and age among students below college level, little attention has been given to such efforts among college students and prospective teachers.

6. Evidence from the literature suggests that a majority of college students are not functioning at the formal level of their cognitive abilities. Since this stage is essential in learning science concepts and processes, some of college students' difficulties in learning science seems to be attributed to the lack of formal abilities.

In light of the fact that science-processes skills are an important aspect of science education and that the new trend in teaching and learning science puts more emphasis on the inquiry skills, little evidence was encountered in the literature that dealt with factors in college students and prospective teachers' background that might affect or explain science-processes skills. The need for more of such information as part of a continuous effort for the improvement of science education is obvious.

CHAPTER III

RESEARCH DESIGN AND PROCEDURE

This study has been designed to investigate possible relationships between science-processes understanding and cognitive abilities. In addition, experiences in science and mathematics, grade point average, SAT scores, and age, among groups of prospective teachers and college-science majors were investigated for their relation to science-processes understanding. The study sought to answer the following questions:

1) Which of the following variables--cognitive ability, high school and college science experience, college mathematics experience, college grade point average, SAT scores, and age--correlated most frequently with and was useful in explaining science-process understanding among prospective teachers and college science majors?

2) Is there any relationship between science-process achievement and cognitive ability among prospective teachers and college science majors?

3) Is there any significant difference between prospective teachers and college science majors as to their science-process achievement and cognitive ability?

4) Does college-science experience have an effect on science-process understanding among prospective teachers and college science majors?

Population Description and Sample Selection

Prior to the sample selection the following steps were taken to assure compliance with the University of North Carolina at Greensboro, School of Education requirement, and regulation:

1) The study was approved by the Human Subjects Review Committee.

2) Professors who asked their classes to assist with the study were contacted prior to the implementation of the study.

3. The main objectives of the study were understood by the subjects; their participation was voluntary.

Sample

Of the 93 subjects who participated in the study, data for only 85 subjects were used in the final analysis. The data for the other eight subjects were eliminated because they were graduate students.

The actual sample size of 85 subjects consisted of two prospective teachers' groups and one college science majors' group: 37 females were prospective teachers who were early childhood education majors with the mean age of 270.73 months; 23 prospective teachers (one male and 22 females) were intermediate education majors with the mean age of 273.60 months. Both groups of prospective teachers were enrolled in Educational Methods and Teaching courses during the Spring term of 1981.

The college science major group was made up of 25 subjects, 12 males and 13 females, with a mean age of 268.80 months. All subjects of this group were enrolled in a sophomore level Inorganic Chemistry course during the Spring term of 1981.

All 85 subjects were administered the Test of Science Processes (TOSP) and the Test of Logical Thinking (TOLT).

<u>Data Collection</u>

The data collection process included the assessment of the subjects' science process achievement and logical thinking ability, as well as data related to the other variables which were obtained through the students' records.

During the period from January 8, 1981 to February 17, 1981, all students in the sample were administered the Test of Science Processes (TOSP) and the Test of Logical Thinking (TOLT). These tests assessed their science process achievement and logical thinking abilities. To assure consistent testing conditions for all subjects, the researcher administered and supervised all testing processes.

Prior to the testing period the main objectives of the study were discussed, and general test instructions were introduced. Students were asked to attempt all test items and to answer questions to the best of their ability. Scoring procedures were also explained before the examination manuals and answer sheets were distributed to the students. Privacy of test scores was assured.

At the conclusion of the testing period the answer sheets were collected and checked for proper student and group identification. Prior to scoring, tests were coded to assure confidentiality. With written permission by students, the Registrar's Office released SAT scores, age, grade point average, high school and college science experience, and college mathematics experience.

Hypotheses

Hypothesis 1: There is no significant difference in science processes achievement test scores between prospective teachers who were early childhood education majors and college science majors.

Hypothesis 2: There is no significant difference in science-processes achievement test scores between prospective teachers (intermediate education majors) and prospective teachers who are early childhood education majors.

Hypothesis 3: There is no significant difference in science-processes achievement test scores between prospective teachers who are intermediate education majors and college science majors.

Hypothesis 4: There is no significant difference in logical thinking abilities test scores between prospective teachers who are early childhood education majors and college science majors.

Hypothesis 5: There is no significant difference in logical thinking abilities test scores between prospective teachers who are early childhood education majors and prospective teachers who are intermediate education majors.

Hypothesis 6: There is no significant difference in logical thinking abilities test scores between prospective teachers who are intermediate education majors and college science majors.

Hypothesis 7: There is no statistically significant relationship between scores on the Test of Logical Thinking and scores on the Test of Science Processes in college students.

Hypothesis 8: There is no statistically significant relationship between experience in science and scores on the Test of Science Processes in college students.

Hypothesis 9: There is no statistically significant relationship between experience in mathematics and scores on the Test of Science Processes in college students.

Hypothesis 10: There is no statistically significant relationship between SAT scores and scores on the Test of Science Processes in college students.

Hypothesis 11: There is no statistically significant relationship between age and scores on the Test of Science Processes in college students.

Hypothesis 12: There is no statistically significant relationship between grade point average and scores on the Test of Science Processes in college students.

Hypothesis 13: There is no statistically significant relationship between scores on the Test of Logical Thinking and scores on the Test of Science Processes in prospective teachers.

Hypothesis 14: There is no statistically significant relationship between SAT scores and scores on the Test of Science Processes in prospective teachers.

Hypothesis 15: There is no statistically significant relationship between grade point average and scores on the Test of Science Processes in prospective teachers.

Hypothesis 16: There is no statistically significant relationship between experience in science and scores on the Test of Science Processes in prospective teachers.

Hypothesis 17: There is no statistically significant relationship between age and scores on the Test of Science Processes achievement in prospective teachers.

Hypothesis 18: There is no statistically significant relationship between college mathematics experience and scores on the Test of Science Processes in prospective teachers.

Hypothesis 19: There is no statistically significant relationship between scores on the Test of Logical Thinking and scores on the Test of Science Processes in college science majors.

Hypothesis 20: There is no statistically significant relationship between grade point average and scores on the Test of Science Processes achievement in college science majors.

Hypothesis 21: There is no statistically significant relationship between SAT scores and scores on the Test of Science Processes in college science majors.

Hypothesis 22: There is no statistically significant relationship between experience in science and scores on the Test of Science Processes in college science majors.

Hypothesis 23: There is no statistically significant relationship between age and scores on the Test of Science Processes in college science majors.

Hypothesis 24: There is no statistically significant relationship between experience in mathematics and scores on the Test of Science Processes in college science majors.

Definition of Terms

The following definitions are for the benefit of the readers as they are used throughout this dissertation:

Test of Science Processes (TOSP): Instrument designed by Tannenbaum (1971) to assess achievement in the use of the science processes such as observing, comparing, classifying, quantifying, measuring, experimenting, inferring, and predicting.

Test of Logical Thinking (TOLT): Paper-and pencil Piaget-type test, designed by Capie and Tobin (1980) to measure five formal reasoning abilities: controlling variables, proportional reasoning, probablistic reasoning, correlational reasoning, and combinatorial reasoning.

Formal reasoning ability: The highest cognitive ability level among Piaget cognitive states, described in detail in Chapter I of this study.

Scholastic Aptitude Test (SAT): measure designed to assess students' basic reasoning abilities in verbal and mathematical skills. Scores on this test help in estimating the student's capacity to perform at the college level.

Grade Point Average (GPA): Represents student's college grade point average and overall academic standing as reflected in student records (Spring 1981).

High school science experience: The number of science courses taken by the subject during high school years, 9th grade to 12th grade.

College science experience: The number of semester credit hours in college science taken by the subject.

College mathematics experience: number of semester credit hours in mathematics taken by the subject during his college years.

Research Instruments

The main research instruments used in this study are Tannenbaum's (1971) Test of Science Processes (TOSP) to assess science-process skills of the subjects, and Tobin and Capie's (1980) Test of Logical Thinking (TOLT) as a measure of formal reasoning abilities. Both tests are paper-and-pencil, multiple-choice tests which require reading and writing proficiency. Both tests are intended for large group use through direct administration. No clinical experiences are required by students or test administrators.

Test of Science Processes (TOSP)

The TOSP is a paper-and-pencil test designed by Tannenbaum(1971) to assess achievement and weaknesses in the use of the science processes skills. It consists of 96 multiple-choice items developed to measure the following eight different science-processes skills: Observing--9 items; comparing--5 items; classification--13 items; quantification--12 items; measuring--25 items; experimenting--10 items; inferring--14 items, and predicting--8 items.

This instrument requires a total of 73 minutes of actual testing time. Its first 12 questions also require the projection of 35-millimeter color slides. The reliability of the total test scores as reported by the author, using the Kuder-Richardson Formula 20, ranges between 90 and 91. Correlating a group of students' (N = 34) total score on TOSP with their teachers' rating in the knowledge and use of science processes, the author found that the test's criterion-related validity was .48. The test was also found to have content-curricular validity.

The scoring procedure of the test is an objective process done by computer or by hand. Students' answer sheets are scored according to the number of correct answers using the scoring key prepared by the author. The test yields a maximum total raw score of 96 and eight different subscores.

Test of Logical Thinking (TOLT)

This test is a multiple-choice, paper-and-pencil test designed by Capie and Tobin (1980) to measure formal reasoning abilities. The ten-item instrument is similar in content and logical processes to those described by Inhelder and Piaget (1958). The test includes two items for each of the following five formal reasoning modes: 1) Controlling variables, 2) proportional reasoning, 3) probablistic reasoning, 4) correlational reasoning, and 5) combinatorial reasoning. The first eight items of the test deal with the first four reasoning modes using multiple-choice questions. A problem is presented through written statement or a combination of written statement and sketch. Then the subject is asked to select the best problem solution from a number of choices. Next a student chooses the best reason to match his choice from a matching set of choices. The last two items deal with the ability of the subject to write down certain combinations to solve the problem. See Appendix for more details.

The reliability of the test assessed by the authors using Chronbach's α technique is 0.8, from the data set (N = 1523). The criterion-related validity of TOLT was assessed to be 0.8 by correlating a group of subjects' TOLT test scores with their performance on five Piaget tasks designed to assess formal reasoning abilities through clinical interviews. The authors concluded that the test is a reliable measure of formal reasoning ability (Capie & Tobin, 1980).

According to the author's scoring criteria, the subject must have both the problem answer choice and its matching reason correct in order to get one unit for each item. The test yields a total of 10 as a maximum raw score. This reflects the subject's overall reasoning abilities. The test's criteria for determining the subject's stage of cognitive development are as follows: A score of zero or one is indicative of concrete thinking; two or three indicates transitional, and 4-10 indicates formal thought. This study deals only with the overall reasoning ability raw scores for the statistical analysis. No effort was made to classify the subject according to his cognitive stage.

Data Analysis

The statistical analysis of all gathered data related to sample subjects was performed by the University Academic Computer Center (ACC), using the statistical analysis system (SAS) package (Helwig & Council (1979). Data were coded and transferred to punched computer cards.

Analysis of variance (ANOVA) for unbalanced design, which is an option of the SAS General Linear Model (GLM) procedure (Helwig & Council, 1979, p. 245) was applied to test Hypotheses 1 through 6, which dealt with whether a significant difference exists between prospective teachers and college science majors in their science-process achievement and logical thinking abilities.

Pearson Product-Moment Correlation Coefficients were obtained through SAS Correlation Procedure (Helwig & Council, 1979, p. 173) to test Hypotheses 7-24, which were designed to investigate possible relationships between science-process skill achievement and certain independent variables concerning subjects' academic experience and other personal factors.

A stepwise, multiple-regression analysis procedure (Helwig & Council, 1979, p. 391) was also applied from the SAS program to investigate which variables in the subjects' background were useful in predicting performance on the TOSP.

All hypotheses were tested using F-ratio at a .05 confidence level as a basis for the acceptance or rejection of these hypotheses in the null form. The actual statistical analysis of the data will be presented in Chapter IV.

Summary

This chapter presented the main questions of the study, the subject population, sample descriptions, and data collection procedures. Six hypotheses related to comparisons among groups on their performance on TOSP and TOLT, and 18 hypotheses related to the relationship between science-process skills and the independent variables were stated. Definition of terms and a full description of research instruments, including validity, reliability and scoring methods of TOSP and TOLT were given. Statistical techniques used for data analysis were also described. A full statistical analysis and results will be presented in Chapter IV.

CHAPTER IV

ANALYSIS OF DATA

The main objective of this study was to provide a better insight into the relationship between science process achievement and other factors related to the subjects: cognitive abilities, past science and mathematics experience, age, grade point average, and SAT scores. The study also examined which of the above stated independent variables are useful in predicting performance on the test of science processes (TOSP), and whether or not a significant difference exists between prospective teachers and science majors in their performance on TOSP and TOLT. Data on the dependent variable TOSP, and the independent variables related to 93 subjects who participated in the study were gathered by the researcher. However, data for only 85 subjects were used in the actual statistical analysis.

The SAS computer package procedure was used to test for statistical significance of the null hypotheses and to answer the study questions. The following techniques were applied:

1. The descriptive statistics such as means, median, and standard deviation (Table 1) and frequency distribution plots, as well as the testing of the hypothesis that the

Table 1

Mean, Median, Standard Deviation, and Range of All Variables

(College Students, N = 85)

Variable	Mean	Median	STD.DEV.	Range Min.	Range Max.
SAT	912.00	895.00	191.20	500.00	1410.00
HSSci	2.77	3.00	0.94	1.00	5.00
AGE	270.94	256.00	43.27	235.00	462.00
GPA	2.99	2.97	0.60	1.87	4.00
CollSci	16.99	14.00	11.13	6.00	54.00
CollMath	7.67	6.00	2.79	3.00	16.00
TOLT	5.79	6.00	2.73	1.00	10.00
TOSP	74.15	76.00	8.65	54.00	92.00

data come from normally distributed populations, were obtained through SAS univariate procedure (Helwig & Council, 1979, p. 427).

2. Analysis of variance (ANOVA) for unbalanced design and Duncan's (1979) multiple-range test were obtained through SAS General Linear Model (GLM) procedure (Helwig & Council, 1979, p. 245) to test the statistical significance of the null hypotheses 1-6. These were designed to examine whether or not significant differences exist between the group means in their performance on TOSP and TOLT.

3. Pearson's Product-Moment Correlation Coefficient matrix using SAS correlation procedure (Helwig & Council, 1979, p. 173) was also obtained as a measure of the degree of relationship between TOSP total scores and each of the other independent variables.

4. The stepwise, multiple-regression analysis procedure (Helwig & Council, 1979, p. 391) was applied as the statistical technique to rank order the relative contribution and importance of the independent variables to the dependent variable (TOSP).

This chapter presents this study's findings under two sections. Section one contains the descriptive analysis of the data; section two contains a more detailed statistical analysis of the findings.

Descriptive Analysis

Data analysis for college students (over all sample subjects) indicates a wide range of scores on the dependent and independent variables as shown in Table 1. Table 1 shows the ranges, means, median, and standard deviation of the dependent variable, the Test of Science Processes (TOSP), and seven independent variables--SAT scores, number of high school science courses taken, age, grade point average (GPA), number of college science courses taken, number of college mathematics courses taken, and the test of logical thinking (TOLT). Examination of Table 1 reveals the following:

1. The ranges, means, and standard deviation of SAT scores and TOLT of the sample subjects suggest that the sample includes subjects with a varied and broad range of cognitive and academic abilities.

2. While some students scored perfectly on TOLT, which put them in the highest cognitive ability level according to the test criterion, some other subjects obtained scores of one, indicating that there are some subjects who still operate at the concrete level of thinking even though they are college students. This assumption has been proven in the literature. None of the subjects scored perfectly on the TOSP. This led the investigator to conclude that either some of the TOSP items are so difficult that they cannot be answered even by the most

able subjects in this sample, or some of the items are unclear in some way so the subjects are not sure how to answer them.

3. The range, mean, and standard deviation of numbers of college science courses taken also show a broad range of college science experience among the subjects. This was expected because the science majors naturally took a large number of college science courses while the prospective elementary teachers took a limited number.

4. The means of most of the variables were located almost halfway between the minimum and the maximum ranges, indicating that the sample was normally distributed.

Science Processes Achievement Among College Students (Prospective Teachers and Science Majors)

Table 1 shows that the overall subjects' raw scores on the Test of Science Processes (TOSP) ranged from 54.00 to 92.00 with a mean score of 74.15, a median of 76.00 and standard deviation of 8.65. Viewing the raw scores by groups, Table 2 shows the ranges, means, and standard deviations of the subjects' performance on the Test of Science Processes (TOSP) for each group separately and for the entire population of the sample (college students as a whole).

Analysis of variance (ANOVA), applied through General Linear Model SAS procedure (Helwig & Council, 1979, p. 245) and presented in Table 3 reveals a significant difference

Table 2

Overall and By Group Performance on TOSP

Group	Mean	Median	Standard Deviation	Range	
				Minimum	Maximum
Prospective (Early Child-hood Education Majors	71.59		8.53	54.00	86.00
Prospective (Intermediate Majors	73.96		8.41	58.00	86.00
College Science Majors	78.12		7.85	65.00	92.00
College Students (Overall Groups)	74.15		8.65	54.00	92.00

Table 3

Summary Analysis of Variance for Group Main Effect on TOSP

Prospective teachers (early childhood) majors N = 37

Prospective teachers (intermediate) majors N = 23

Science majors N = 25

Source	DF	Sum of Squares	Mean Square	F	PR> F	R^2
Group	2	636.9463	318.2482	4.62	.0126	.1012
			68.9575			
Error	82	5654.5154				
Total	84	6291.0117				

between groups in their performance on the Test of Science Processes (TOSP). Further analysis using Duncan's Multiple-Range Test (Table 4) showed that the science majors group performed significantly better on the TOSP than the prospective teachers who were early childhood education majors. But science majors did not perform significantly better than the prospective teachers who were intermediate education majors. The difference between the prospective teachers groups (early childhood education and intermediate education majors) was not significant. Therefore, the science majors group is able to use science processes better than prospective teachers who are early childhood majors with prospective teachers who are intermediate majors standing somewhere between the two groups.

Logical Thinking Abilities in Prospective Teachers and Science Majors

The mean, standard deviation, and range for overall sample subjects' (college students') performance on the Test of Logical Thinking (TOLT) were 5.79, 2.73, and 1 to 10 respectively, as shown in Table 5. The table also presents subjects' performance on the Test of Logical Thinking (TOLT) by group.

Table 5 showed that the college science majors group had a mean of 7.04, which is the highest, and prospective teachers who were early childhood majors had the lowest mean of 4.92. ANOVA (Table 6) indicates statistically

Table 4

Duncan's Multiple Range Test for Differences Among Groups on TOSP

Group	N	Mean	Grouping*	
3. Science Majors	25	78.12	A	
			A	
1. Prospective Teachers (Intermediate Majors)	23	73.96	A	B
				B
2. Prospective Teachers (Childhood Majors)	37	71.59		B

Alpha level = .05 DF = 82.00

*Means with the same letter are not significantly different.

Table 5

Overall and Group Performance on TOLT

Group	Mean	Median	Standard Deviation	Range	
				Minimum	Maximum
Prospective Teachers (Early Childhood Majors)	4.92		2.79	1	9
Prospective Teachers (Intermediate Majors)	5.82		2.13	2	9
College Science Majors	7.04		2.72	1	10
College Students (All Groups)	5.79		2.73	1	10

Table 6

Summary Analysis of Variance for Group Main Effect on TOLT

Prospective teachers (early childhood) majors N = 37

Prospective teachers (intermediate) majors N = 22

Science majors N = 25

Source	DF	Sum of Squares	Mean Square	F-Value	PR>F	R^2
Group	2	67.1534	33.5767	4.92	0.0096	0.1083
Error	81	55.9895	6.8270			
Total	83	620.1429				

significant differences among prospective teachers who were early childhood majors, prospective teachers who were intermediate majors, and college science majors on their logical thinking abilities. Duncan's multiple range test (Table 7) showed that college science majors performed significantly better than prospective teachers who were early childhood majors. Data also indicated that there is no significant difference between prospective teachers' groups in their logical thinking abilities.

Correlation and Regression Analysis

Pearson Product-Moment Correlation Coefficient Analysis was performed to assess the degree of relationships between the dependent variable (TOSP) and each of the independent variables. Stepwise regression analysis was also applied to determine which of the independent variables were significant predictors of students' science processes achievement.

College Students (Overall Sample Subjects)

Table 8 shows Pearson's *r* Coefficient and its related statistical significance between the dependent and each of the independent variables for college students (overall sample subjects), and indicates a statistically significant positive relationship between science processes achievement and each of the following independent variables: SAT, high school science, grade point average, college science

Table 7

Duncan's Multiple Range Test for Differences Among Groups on TOSP

Group	N	Mean	Grouping*	
3. Science Majors	25	7.04	A	
			A	
1. Prospective Teachers (Intermediate Majors)	22	5.82	A	B
				B
2. Prospective Teachers (Early Childhood Majors)	37	4.92		B

Alpha level = 0.05 DF = 81 MS = 6.83

*Means with the same letter are not significantly different.

Table 8

Pearson's Correlation Coefficient for College Students

(Overall Sample Subjects)

	SAT	HSSCI	Age	GPA	CollSci	CollMath	TOLT	TOSP
SAT(2)	1.0000 .0000	0.2935 0.0091	0.0586 0.6105	0.2267 .0459	0.3002 0.0080	0.0527 0.6470	0.4477 0.0001	0.4448* 0.0001**
HSSCI		1.000 0.000	-0.2406 .0266	-0.0496 0.6524	0.3164 .0034	0.2568 .0177	0.1594 0.1474	0.2096* 0.0542**
Age			1.0000 0.0000	0.2228 .0404	-0.0100 0.9277	-0.0262 .8120	0.0922 0.4039	0.1573* 0.1505**
GPA(3)				1.0000 .0000	-0.0817 0.4603	-0.0262 .8118	0.3389 0.0016	0.3851* 0.0003**
CollSci					1.0000 0.0000	0.2489 0.0224	0.3144 0.0038	0.2535* 0.0200**
CollMath						1.0000 0.0000	0.2105 0.0546	0.1726* 0.1142**
TOLT(1)							1.0000 0.0000	0.5825* 0.0001**
TOSP								1.0000 0.0000

* Pearson's r
**Alpha probability

experience, and logical thinking ability among college students. Stepwise regression analysis indicated that Test of Logical Thinking (TOLT), SAT, and grade point average (GPA) with a multiple R-Square of 0.4186 are the best predictors of science processes achievement among college students (over all sample subjects).

<u>Prospective Teachers</u>

The computed Pearson Correlation Coefficients illustrated in Table 9 indicates that the Test of Logical Thinking (TOLT), SAT, and grade point average (GPA) are significantly correlated with the dependent variable science processes achievement, as measured by TOSP within prospective teachers (both early childhood and intermediate majors).

Regression analysis related to prospective teacher subjects revealed that the Test of Logical Thinking (TOLT) and SAT with multiple R-square of 0.2732, are the best predictors of science processes achievement as measured by TOSP.

<u>College Science Majors</u>

Table 10, which presents Pearson Correlation Coefficient between the criterion variable TOSP and the independent variables, showed that the Test of Logical Thinking (TOLT) and grade point average are the only two variables that correlate highly and significantly with science processes achievement as measured by TOSP within science majors group. The stepwise regression analysis indicates that the Test of

Table 9

Pearson's Correlation Coefficient for Prospective Teachers

	SAT	HSSCi	Age	GPA	CollSci	CollMath	TOLT	TOSP
SAT	1.0000 0.0000	0.1616 0.2478	-0.0197 0.8888	0.2011 0.1487	0.0582 0.6816	-0.0582 0.6792	0.4767 0.0003	0.4303* 0.0013**
HSSci		1.0000 0.0000	-0.2883 0.0255	-0.0070 0.9575	0.2051 0.1191	0.1388 0.2902	0.0922 0.4872	0.1485* 0.2576**
Age			1.0000 0.0000	0.3304 0.0099	-0.0092 0.9449	-0.1456 0.2671	0.0245 0.8538	0.1378* 0.2936**
GPA				1.0000 0.0000	-0.0771 0.5614	-0.1511 0.2492	0.2729 0.0365	0.3374* 0.0084**
CollSci					1.0000 0.0000	0.0924 0.4864	-0.0215 0.8726	0.0916* 0.4901**
CollMath						1.0000 0.0000	0.0418 0.7532	-0.0037* 0.9774**
TOLT							1.0000 0.0000	0.4614* 0.0002**
TOSP								1.0000 0.0000

*Pearson's r
**Alpha probability

Table 10

Pearson's Correlation Coefficient for College Science Majors

	SAT	HSSci	Age	GPA	CollSci	CollMath	TOLT	TOSP
SAT	1.0000 0.0000	0.1827 0.3820	0.0676 0.7481	0.3105 0.1309	0.1006 0.6323	-0.0866 0.6806	0.2296 0.2697	0.2909* 0.1583**
HSSci		1.0000 0.0000	-0.1067 0.6117	-0.1310 0.5324	-0.1150 0.5840	0.1672 0.4244	-0.1419 0.4887	0.1012* 0.6304**
Age			1.0000 0.0000	-0.0274 0.8964	0.0569 0.7872	0.2722 0.1881	0.3494 0.0869	0.2985* 0.1473**
GPA				1.0000 0.0000	-0.0757 0.7191	0.1763 0.3992	0.5453 0.0048	0.5861* .0021**
CollSci					1.0000 0.0000	0.0425 0.8402	0.3215 0.1171	0.1033* 0.6233**
CollMath						1.0000 0.0000	0.2747 0.1839	0.2750* 0.1833**
TOLT							1.0000 0.0000	0.7440* 0.0001**
TOSP								1.0000 0.0000

*Pearson's r
**Alpha probability

Logical Thinking (TOLT) with an R-Square of 0.5536 was the only significant predictor that can explain 55 percent of the variability in science processes achievement among the science majors group.

Statistical Analysis

Data obtained from the analysis of variance through SAS Procedure General Linear Model GLM (Helwig & Council, 1979, p. 245) (Tables 3 and 6), and Duncan's multiple range test (Tables 4 and 7) were used to test Hypotheses 1 through 6 related to whether or not a significant difference exists between prospective teachers who were early childhood majors, prospective teachers who were intermediate majors, and college science majors in their performances on TOSP and TOLT. Pearson Product-Moment Correlation Coefficient matrix (Tables 8, 9, and 10) obtained through SAS Correlation Procedure (Helwig and Council, 1979, p. 173), were used to test the null hypotheses 7-24 dealing with the relationships between the dependent variable TOSP and various independent variables.

Stepwise multiple-regression analysis data were used in testing which of the independent variables are significant predictors of the dependent measure TOSP. Prior to the selection of the best regression equation, which might include the best significant predictors of science processes achievement (TOSP), the following criteria were used as limiting factors:

1. The best predictive model had to have a significant F-ratio at the .05 level or lower level of significance.

2. Any new model would not be considered unless the coefficient of determination (R^2) increased by at least .01 over the previous equation.

3. Any variable included in the final model must be significant at the .05 level or lower; however, one variable at .10 level per model might be accepted.

Any equation which failed to meet these criteria in the stepwise regression analysis was not considered for the final equation. As a result of stepwise multiple regression application on the data and on the basis of the above criteria, three best predictive models had to be chosen: first, the best predictive equation for predicting science processes achievement (TOSP) within college students (over-all sample subjects), second, the best predictive equation for prospective elementary school teachers; third, the best predictive model for college science majors.

Testing of the Null Hypotheses

The hypothesis testing process and its related data tables and analysis are presented in the following sections.

Hypotheses 1-6 Related to Prospective Teachers and College Science Majors' Performance on TOSP and TOLT

While SAS procedure General Linear Model GLM (Helwig & Council, 1979, p. 245) (Table 3) shows that there is a main group effect on TOSP [F = 4.62, df = 2.82, PR > F =

.0126], Table 6 presents evidence that there is also a main group effect on TOLT [F = 4.92, df = 2.81, PR > F = 0.0096]. Therefore, Duncan's (1979, p. 191) Multiple Range Test procedure was applied to test Hypotheses 1 through 6.

Hypothesis 1: There is no significant difference in science processes achievement test scores between prospective teachers who were early childhood education majors and college science majors.

Table 4 indicates that the college science majors group with the TOSP mean of 78.12 and prospective teachers (early childhood majors) group with a TOSP mean of 71.59, are significantly different (at .05 level of significance) in their science processes performance. Hypothesis 1 can be rejected with the conclusion that the college science majors group is superior to the prospective teachers who were early childhood education majors group in science processes achievement.

Hypothesis 2: There is no significant difference in science processes achievement test scores between prospective teachers who were intermediate education majors and prospective teachers who were early childhood education majors.

Data in Table 4 indicate that Hypothesis 2 could not be rejected at .05 level of significance. Therefore the conclusion is that there was no significant difference in science processes achievement between the two prospective teachers' groups.

Hypothesis 3: There is no significant difference in science processes achievement test scores between prospective teachers who were intermediate education majors and college science majors.

Table 4 shows that Hypothesis 3 could not be rejected at the .05 level of significance. There was no significant difference in science processes achievement between prospective teachers who were intermediate education majors and college science majors.

Hypothesis 4: There is no significant difference in logical thinking abilities test scores between prospective teachers who were early childhood education majors and college science majors.

Table 7 indicates that college science majors group with a TOLT mean of 7.04 is significantly superior to the prospective teachers who were early childhood education majors group with a TOLT mean of 4.92 at the .05 level of confidence. Therefore, Hypothesis 4 could be rejected. It can be concluded that there is a significant difference in logical thinking abilities between the prospective teachers who were early childhood education majors and college science majors.

Hypothesis 5: There is no significant difference in logical thinking abilities test scores between prospective teachers who were intermediate education majors and prospective teachers who were early childhood education majors.

Data in Table 7 indicate that Hypothesis 5 could not be rejected at the .05 level of significance. The conclusion is that there was no significant difference in logical thinking abilities between the two prospective teachers' groups.

Hypothesis 6: There is no significant difference in logical thinking abilities test scores between prospective teachers who were intermediate education majors and college science majors.

Table 7 shows that Hypothesis 6 could not be rejected at the .05 level of significance; accordingly, there was no significant difference in logical thinking abilities between the prospective teachers who were intermediate education majors and the college science majors.

Hypotheses Related to the Relationships Between Science Processes Achievement and the Independent Variables in College Students (Overall Sample Subjects)

Hypothesis 7: There is no statistically significant relationship between scores on the Test of Logical Thinking and scores on the Test of Science Processes in college students.

Hypothesis 7 was tested by computing Pearson's Product-Moment Correlation Coefficient (Table 8), using SAS Correlation Procedure (Helwig & Council, 1979, p. 173). The correlation coefficient of .58 (Table 8), which was statistically significant at .01, indicated that Hypothesis 7 should be rejected, with the conclusion that there was a significant relationship between science processes achievement and logical thinking abilities among college students. The computed coefficient of determination (R-square) for TOLT (Table 11) was .339, which shows that logical thinking abilities accounted for 34% of the variability in science processes achievement.

Hypothesis 8: There is no statistically significant relationship between experience in science and scores on the Test of Science Processes in college students.

Table 8 shows a low but significant correlation coefficient of .209 between high school science and TOSP and a coefficient of .256 between college science and TOSP. These findings suggested that Hypothesis 8 be rejected. There was a significant relationship between science experience (high school and college) and science processes achievement with college students (overall sample subjects). A coefficient of determination of .064 for college science and .044 for high school science (Table 11) indicated that college science has been able to account for only 6.5% of the variability in TOSP which was unexpectedly low. The 4.4% contribution by high school science was less than that of college science by only 2%.

Hypothesis 9: There is no statistically significant relationship between experience in mathematics and scores on the Test of Science Processes in college students.

Table 11

*Summary of Simple Regression Analysis

Contributions of Each Variable Independently to the Variability in TOSP

College Students (Overall Sample Subjects) N = 85

Variable	R^2	% Contribution	F	PR>F
TOLT	0.3393	34.00	42.10	0.0001
CollSci	0.0643	6.4	5.63	0.02
HSSci	0.0439	4.4	3.81	0.0542
CollMath	0.0298	2.98	2.55	0.1142
SAT	0.1979	19.8	18.75	0.0001
Age	0.0247	2.47	2.11	0.1505
GPA	0.1482	14.8	14.45	0.0003

*The criterion variable was regressed on each predictor variable.

Hypothesis 9 was tested by calculating Pearson's Correlation Coefficient (Table 8). A correlation coefficient of 1.73 was not significant at .05 level. Therefore, Hypothesis 9 could not be rejected. There was no significant relationship between experience in mathematics and science processes achievement in college students.

Hypothesis 10: There is no statistically significant relationship between SAT scores and scores on the Test of Science Processes in college students.

The Pearson Product Moment Correlation Coefficient (Table 8) was used to test Hypothesis 10. With a correlation coefficient of .445 which was significant at .01 level, Hypothesis 10 was rejected with the conclusion that there is a significant relationship between SAT scores and science processes achievement in college students. The coefficient of determination of .198 for SAT (Table 11) shows that SAT alone accounts for 19.8% in science processes achievement variability among college students.

Hypothesis 11: There is no statistically significant relationship between age and scores on the Test of Science Processes in college students.

The correlation coefficient for age shown in Table 8 was not significant at .05. Hypothesis 11 therefore was not rejected. There was no significant relationship between age and science processes performance within college students.

Hypothesis 12: There is no statistically significant relationship between grade point average and scores on the Test of Science Processes in college students.

The Pearson Product Moment Correlation Coefficiant of .385 which was significant at .01 level (Table 8), indicates that Hypothesis 12 should be rejected. There was a significant relationship between grade point average and science processes achievement with college students. With a coefficient of determination of .148 (Table 11) grade point average accounted for 14.8% of the variability in science processes achievement of college students.

Hypotheses Related to the Relationship Between Science Processes Achievement and Other Variables in Prospective Teachers.

Hypothesis 13: There is no statistically significant relationship between scores on the Test of Logical Thinking and scores on the Test of Science Processes in prospective teachers.

Hypothesis 13 was tested by computing Pearson's Product-Moment Correlation Coefficient (Table 9) using SAS correlation procedure (Helwig & Council, 1979, p. 173). The correlation coefficient of .46 (Table 9) which was significant at .01 level indicated that Hypothesis 13 could be rejected; there was a significant relationship between logical thinking abilities and science processes achievement in prospective teachers. The coefficient of determination (R-square) of 0.213 (Table 12) for TOLT shows that logical

Table 12

Summary of Simple Regression Analysis

Contribution of Each Variable Independently to

Variability in TOSP (Prospective Teachers) N = 60

Variable	R^2	% Contribution	F	PR>F
TOLT	0.2129	21.3	15.42	0.0002
CollSci	0.0084	0.84	0.48	0.4901
HSSci	0.0220	2.20	1.31	0.2576
CollMath	0.0000	0.00	0.00	0.9774
SAT	0.1851	18.5	11.59	0.0013
Age	0.0190	1.90	1.12	0.2936
GPA	0.1138	11.38	7.45	0.0084

thinking abilities accounted for or explained 21.3% of the variability in science processes achievement in prospective teachers.

Hypothesis 14: There is no statistically significant relationship between SAT scores and scores on the Test of Science Processes in prospective teachers.

The correlation coefficient of 0.43 which was significant at the .01 level (Table 9) indicated that Hypothesis 14 could be rejected with the conclusion that there was a significant relationship between SAT scores and science processes achievement in prospective teachers. The coefficient of determination of .185 (Table 12 for SAT, calculated by simple regression analysis using SAS computer program (Helwig & Council, 1979, p. 245), shows that SAT accounted for 18.5% of the variability in science processes achievement within prospective teachers.

Hypothesis 15: There is no statistically significant relationship between grade point average and scores on the Test of Science Processes in prospective teachers.

The correlation coefficient of .337 (Table 9) which was significant at the .01 level, indicated that Hypothesis 15 could be rejected with the conclusion that there was a significant relationship betweem grade point average amd science processes achievement. The coefficient of determination of 0.114 (Table 12) for grade point average, calculated by the simple regression analysis SAS program

(Helwig & Council, 1979, p. 245) shows that grade point average accounted for 11.4% of the variability in science process achievement in prospective teachers.

Hypothesis 16: There is no statistically significant relationship between experience in science and scores on the Test of Science Processes in prospective teachers.

The correlation coefficients of 0.148 for high school science and 0.092 for college science (Table 9) were not significant at the .05 level. Therefore Hypothesis 16 was accepted with the conclusion that there was no significant relationship between science experience and science processes achievement within prospective teachers. It is interesting to note that while both high school and college science experience were correlated weakly with science processes achievement within college students (overall sample subjects), prospective teachers' high school and college science experience was not significantly correlated with science processes achievement.

Hypotheses 17: There is no significant relationship between age and scores on the Test of Science Processes achievement in prospective teachers.

Hypothesis 18: There is no statistically significant relationship between college mathematics experience and scores on the Test of Science Processes in prospective teachers.

The correlation coefficients of 0.138 for age and -0.004 for college mathematics experience (Table 9) were not significant at the 0.05 level, which indicated that Hypotheses 17 and 18 could be accepted. Therefore, there was no significant relationship between age and science processes achievement, as well as no significant relationship between mathematics experience and science processes achievement within prospective teachers.

Hypotheses Related to the Relationship Between Science Processes Achievement and Other Variables in College Science Majors

Hypothesis 19: There is no statistically significant relationship between scores on the Test of Logical Thinking and scores on the Test of Science Processes in college science majors.

Hypothesis 19 was tested by computing Pearson's Product-Moment Correlation Coefficient (Table 10), using SAS correlation procedure (Helwig & Council, 1979, p. 173). The high correlation coefficient of .744 (Table 10) which was significant at .01 level indicated that Hypothesis 19 could be rejected, with the conclusion that there was a significant relationship between logical thinking abilities and science processes achievement in college science majors.

The coefficient of determination of .554 (Table 13) for logical thinking abilities, calculated by simple

Table 13

Summary of Simple Regression Analysis

Contribution of Each Variable Independently to the

Variability in TOSP (College Science Majors) N = 25

Variable	R^2	% Contribution	F	PR>F
TOLT	.5537	55.4	28.53	0.0001
CollSci	0.0166	1.66	0.25	0.6233
HSSci	0.0102	1.02	0.24	0.6304
CollMath	0.0756	7.56	1.88	0.1833
SAT	0.0846	8.46	2.13	0.1583
Age	0.0890	8.90	2.25	0.1473
GPA	0.3435	34.4	12.03	0.0021

regression analysis using SAS computer program (Helwig & Council, 1979, p. 245), shows that logical thinking abilities accounted for 55.4% of the variability in science processes achievement in college science majors. The correlation of .744 between science processes and logical thinking abilities within college science majors was higher than that of prospective teachers and college students (overall sample).

Hypothesis 20: There is no statistically significant relationship between grade point average and scores on the Test of Science Processes achievement in college science majors.

The correlation coefficient of .586 (Table 10), which was significant at the .01 level indicated that Hypotheses 20 could be rejected with the conclusion that there was a significant relationship between grade point average and science processes achievement. The coefficient of determination of 0.344 (Table 13) for grade point average calculated by simple regression analysis using SAS computer program (Helwig & Council, 1979, p. 245) shows that grade point average accounted for 34.4% of the variability in science processes achievement within college science majors. Grade point average and science processes achievement correlated significantly, $r = .586$, in college science majors, which is higher than that of overall college students, r = .385, with the prospective teachers having the lowest significant correlation, r = .337.

Hypothesis 21: There is no statistically significant relationship between SAT scores and scores on the Test of Science Processes in college science majors.

Hypothesis 22. There is no statistically significant relationship between experience in science and scores on the Test of Science Processes in college science majors.

Hypothesis 23: There is no statistically significant relationship between age and scores on the Test of Science Processes in college science majors.

Hypothesis 24: There is no statistically significant relationship between experience in mathematics and scores on the Test of Science Processes in college science majors.

The correlation coefficients (Table 10) for SAT, experience in science, age, and experience in mathematics were not significant at the .05 level. Therefore the null hypotheses 21, 22, 23, and 24 were accepted. There was no significant relationship between science processes achievement and SAT, experience in science, age, and experience in mathematics within college science majors.

<u>Importance of Independent Variables as Predictors of Science Processes Achievement</u>

In order to isolate and determine the relative importance of the significant predictors of science processes achievement scores, as indicated in the study's main objectives, the stepwise multiple regression analyses were performed using SAS stepwise procedure (Helwig & Council, 1979), p. 391).

The stepwise regression analysis for the dependent variable (Tables 14-18) resulted in the selection and rank order contribution of the statistically significant predictors which constitute the best prediction model of science processes achievement for college students, prospective teachers, and college science majors, separately.

Stepwise regression analysis data (Table 14) show that TOLT, SAT, and GPA are the best predictors of science processes achievement in college students (overall sample subjects). These variables together with an R-Square of 0.4186, explained 41% of variability in the TOSP. TOLT alone with an R-Square of 36.61 (Table 15) ranked as the best predictor, explaining 36.61% of variability in TOSP. SAT ranked as the second best predictor increasing the explained variability in TOSP from 36.21% to 39.46% (Table 15). GPA was the third best predictor increasing the explained variability in TOSP in college students from 39.46% to 41.86% (Table 15). Although college and high school science were significantly correlated with science processes achievement, stepwise regression analysis shows that these two variables are not significant predictors when they entered with the other independent variables in stepwise multiple regression. It seems that the intercorrelation between the independent variables

Table 14

Stepwise Regression Analysis TOLT, GPA, and SAT

as Best Predictors of TOSP Scores

(College Students N = 85)

Source	DF	Sum of Squares	Mean Squares	F	PR>F	R^2
Regression	3	2275.1330	758.3777	17.52	0.0001	0.4186
Error	73	3160.0358	43.2882			
Total	76	5435.1688				

	B-Value	Type II Sum of Squares	F	PR>F
Intercept	51.2673			
SAT	0.0087	165.5802	3.83	0.0543
GPA	2.4449	130.3967	3.01	0.0869
TOLT	1.3678	768.0221	17.74	0.0001

Table 15

Stepwise Regression Analysis: Rank Order Contribution of TOLT, SAT, and GPA to the Prediction of Scores on the TOSP (College Students, N = 85)

Order of Variable as entered into the model	Criterion	Predictor	R^2 Change	% Contribution	DF_1	DF_2	F	PR>F
1	TOSP	TOLT	0.3621	36.21	1	75	42.57	0.0001
2	TOSP	SAT	0.3946	39.46	2	74	3.98	0.0498
3	TOSP	GPA	0.4186	41.86	3	73	3.01	0.0869
4	TOSP	HSSci	0.4377	43.77	4	72	2.45	0.1221

Table 16

Stepwise Multiple Regression Analysis TOLT and SAT Scores

as a Best Predictor of TOSP Scores

(Overall Prospective Teachers N = 60)

Source	DF	Sum of Squares	Mean Squares	F	PR>F	R^2
Regression	2	950.5016	475.2508	9.21	0.0004	0.2733
Error	49	2527.5753	51.5832			
Total	51	3478.0769				

	B-Value	Type II Sum of Squares	F	PR>F
Intercept	56.1240			
SAT	0.0124	153.4291	2.97	0.0909
TOLT	1.1257	335.0606	6.50	0.0140

themselves, as shown in Table 8, contributed to the exclusion of college and high school science (Kerlinger & Pedhazur, 1973) as well as the low correlation between each of the two variables and the dependent variable.

Table 16 shows that TOLT and SAT scores are the best predictors of science processes achievement within overall prospective teachers groups. The best prediction model [F = 9.21, df = 2,49, PR > F = 0.0004] with R-Square of .2733 indicated that both variables together can explain 27.33% of variability in TOSP. Table 17 indicates that TOLT is a better predictor than SAT. TOLT entered the model in the first step with an R-Square of 22.92; it alone can explain 22.92% of variability in TOSP scores within prospective teachers. SAT was the second significant predictor, increasing the R-Square from 22.92 to 27.33. Therefore SAT improved the ability of the model to explain TOSP variability within prospective teachers by 4.41%. Although correlation and simple regression analysis (Tables 9 and 12) show that GPA can be a significant predictor of TOSP, stepwise multiple regression analysis indicates that GPA is not a significant predictor when entered with TOLT and SAT.

Table 18 indicates that among all independent variables in the stepwise multiple regressions, TOLT is the only significant predictor of science processes scores in the college science majors group. The best prediction model

Table 17

Stepwise Multiple Regression Analysis: Rank Order Contribution of TOLT and SAT to the Prediction of Scores on the TOSP

(Over All Prospective Teachers N = 60)

Order of Variables as entered into the model	Criterion	Predictor	R^2 Change	% Contribution	DF_1	DF_2	F	PR>F
1	TOSP	TOLT	0.2292	22.92	1	50	14.87	0.0003
2	TOSP	SAT	0.2733	27.33	2	49	6.50	0.0909

Table 18

Stepwise Regression Analysis for TOLT as a Best Predictor

of TOSP Scores (College Science Majors N = 25)

Source	DF	Sum of Squares	Mean Squares	F	PR>F	R^2
Regression	1	819.7874	819.7874	28.53	0.0001	0.5537
Error	23	660.8526	28.7327			
Total	24	1480.6400				

	B-Value	Type II Sum of Squares	F	PR>F
Intercept	62.9674			
TOLT	2.1524	819.7874	28.53	0.0001

Note. Only TOLT is a significant predictor of TOSP within college science majors

[F = 28.53, df = 2,23, PR > F = 0.0001] with R-Square of 0.5537 shows that TOLT alone accounted for 55.37% of variability in TOSP scores within science majors group. Although simple regression shows that GPA independently accounts for 34.4% of variability in TOSP, stepwise multiple regression indicates that GPA is not a significant predictor when entered with TOLT. It seems that whatever variability can be explained by GPA, TOLT is able to account for it because of the moderate correlation between TOLT and GPA (Table 10) within the science majors group (Kerlinger & Pedhazur, 1973).

College Science Experience and Students' Ability to Use Science Processes

The simple and stepwise multiple regression analyses data (Tables 11, 14, and 15) for college students (overall sample subjects) introduced in previous sections of this chapter will be used to examine one of this study's main questions: does college science experience have any effect on college students' science processes skills? Although simple regression analysis (Table 11) shows that college science experience accounted for 6.4% of variability in TOSP, stepwise multiple regression analysis for college students (Tables 14 and 15) indicates that college science experience is not a significant predictor when entered with TOLT, SAT, and GPA. The failure of college science experience to be a significant predictor in stepwise analysis does not necessarily mean that it did not have any effect on science processes achievement within college students. Given the facts that college science experience correlates significantly, r = .339 (Table 8) with TOLT, that TOLT is the most significant predictor of TOSP, and that college science is a significant predictor of TOLT (Table 19), it might be concluded that college science experience contributed to TOSP in an indirect way through TOLT. Given the above argument, and in light of the finding that college science experience independently accounts for 6.4% of variability in TOSP, it is reasonable to conclude that college science experience did improve college students' (overall sample subjects) science processes skills through logical thinking abilities (TOLT).

Summary

The first section of Chapter IV dealt with overall descriptive analysis of findings. It included an overall view of the college students' performance on TOSP, TOLT, and other independent variables. The findings related to group comparison on their achievement on TOSP and TOLT, and to the relationship between science processes achievement and each of the independent variables were also briefly discussed.

The second part of Chapter IV dealt with the statistical analysis and techniques (Pearson Product-Moment Correlation coefficient analysis, analysis of variance,

Table 19

Stepwise Regression Analysis of TOLT as the Independent Variable

(College Students over All Sample Subject N = 85)

Source	DF	Sum of Squares	Mean Square	F	PR>F	R^2
Regression	3	203.7768	67.9256	13.08	0.0001	0.3496
Error	73	379.0284	5.1922			
Total	76	582.8052				

	B-Value	Type II Sum of Squares	F	PR>F
Intercept	-4.1520			
SAT	0.0046	50.4723	9.72	0.0026
GPA	1.5786	59.8443	11.53	0.0011
CollSci	0.05959	31.4343	6.05	0.0162

*All independent variables regressed on TOLT to examine whether college science is a significant predictor of TOLT.

simple and multiple regression analysis) used to analyze the data to test the 24 hypotheses stated in Chapter III.

The hypotheses testing processes include the following:

1. The testing of hypotheses 1-6 dealt with group comparison on their performances on TOSP and TOLT. The detection of group main effect through analysis of variance technique (ANOVA) led to the application of Duncan's Multiple Range Test to obtain data (Tables 3, 4, 5, and 7) to test hypotheses 1-6. The test of the first six hypotheses revealed that the college science majors group was significantly superior to the group of prospective teachers who were early childhood education majors on both TOSP and TOLT, with no significant difference between college science majors and prospective teachers who were intermediate education majors on both TOSP and TOLT, and no significant difference between the two prospective teachers' groups on TOSP and TOLT.

A summary of hypotheses testing, including hypotheses 1-6, is presented in Table 20.

2. Hypotheses 7-24 deal with the relationship between TOSP and each of the independent variables among college students (overall sample subjects), prospective teachers (both prospective teachers' groups) and college science majors.

Pearson Product-Moment Correlation data (Tables 8, 9, and 10) and sample regression analysis data (Tables 11,

Table 20

Summary of the Hypotheses Testing

Hypothesis #	Type Test Used	Result
	Hypotheses 1-6: Comparisons Among Groups on TOSP and TOLT	
1.	Duncan's Multiple Range Test	Rejected
2.	Duncan's Multiple Range Test	Accepted
3.	Duncan's Multiple Range Test	Accepted
4.	Duncan's Multiple Range Test	Rejected
5.	Duncan's Multiple Range Test	Accepted
6.	Duncan's Multiple Range Test	Accepted
	Hypotheses 7-12: Relationship Between TOSP and Each Independent Variable within College Students	
7.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
8.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
9.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
10.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
11.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
12.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected

Table 20 (continued)

Hypotheses #	Type Test Used	Result
	Hypotheses 13-18: Relationship Between TOSP and Each Independent Variable Within Prospective Teachers	
13.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
14.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
15.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
16.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
17.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
18.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
	Hypotheses 19-24: Relationship Between TOSP and Each Independent Variable, Within College Science Majors	
19.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
20.	Pearson Correlation Coefficient and Simple Regression Analysis	Rejected
21.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
22.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
23.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted
24.	Pearson Correlation Coefficient and Simple Regression Analysis	Accepted

12, and 13) were used to test hypotheses 7-24. Testing of hypotheses 7-12 revealed that there is a significant relationship between TOSP and each of the following: TOLT, SAT, GPA, high school and college science within the college students group.

Testing of hypotheses 13-18 revealed that there is a significant relationship between TOSP and TOLT, SAT and GPA with both prospective teachers' groups.

Testing of hypotheses 19-24 shows that TOSP is significantly related to TOLT and GPA in college science majors group. Summary of testing of hypotheses 7-24 is presented in Table 20.

Stepwise multiple regression analysis data (Tables 14, 15, 16, 17, and 18) identified TOLT, SAT, and GPA as the best predictors of TOSP scores within college students, TOLT and SAT as the best predictors of TOSP scores within prospective teachers, and TOLT constitutes the best predictor of TOSP scores within college science majors. Findings related to the effect of college science experience on science processes skills were also discussed.

Chapter V will include a discussion of the findings presented in this chapter.

CHAPTER V

DISCUSSION OF FINDINGS, SUMMARY AND CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

This study has been designed to investigate the relationship between science processes achievement and the following independent variables: logical thinking abilities, experience in science and mathematics, grade point average, SAT scores, and age among a group of 85 students (60 prospective teachers and 25 college science majors). Comparison of prospective teachers groups' performance on a science processes achievement test and a logical thinking abilities test with that of a college science majors' group, and the effect of college science experience on science processes skills within college students were also investigated.

Data on the dependent and independent variables, related to the sample subjects, were gathered by the researcher and subjected to statistical analysis: Pearson Product-Moment Correlation Coefficient, Analysis of Variance, simple regression, and stepwise multiple regression analyses to test the 24 null hypotheses and to answer the study's main questions.

Chapter IV included hypotheses testing processes and the full details of the data analysis, based on the findings of this study. This chapter presents discussions of findings conclusions, and recommendations and implications.

Discussion of Findings

The statistical analyses introduced in Chapter IV resulted in the rejection of one null hypothesis and acceptance of two null hypotheses related to groups' differences in science processes achievement scores, and the rejection of one null hypothesis and acceptance of two null hypotheses related to groups' differences due to their logical thinking abilities scores.

Out of the 18 null hypotheses related to the relationship between science processes achievement and the independent variables, 4 null hypotheses were rejected and 2 null hypotheses were accepted within college students (overall sample subjects); 3 null hypotheses were rejected and 3 null hypotheses were accepted within both prospective teachers' groups; and 2 null hypotheses were rejected and 4 null hypotheses were accepted within college science majors' group.

The discussion of findings will be presented under the following headings: first, differences between groups due to their science processes achievement scores; second, differences between groups due to their logical thinking abilities scores; third, variables in subjects' background that correlate with and are useful in predicting science processes achievement scores within college students (overall sample subjects); fourth, variables in subjects' background that correlate with and are useful in predicting science processes achievement scores within both prospective teachers' groups; fifth, variables in subjects' background that correlate with and are useful in predicting science processes achievement scores within college science majors.

Differences Between Groups Due to Their Science Processes Achievement Scores

Examination of the science processes achievement mean scores for the three groups revealed that the college science majors' group with TOSP mean score of 78.12 had the highest mean score; the group of prospective teachers who were early childhood education majors, with TOSP mean score of 71.59 had the lowest mean score, and the group of prospective teachers who were intermediate education majors, with TOSP mean score of 73.96, was somewhere between the two groups. Although the science majors group's mean score was higher than both prospective teachers groups' means, it was significantly superior only to the group of prospective teachers who were early childhood education majors. It was not significantly different from the TOSP mean score of the group of prospective teachers who were intermediate education majors. Comparison of the two prospective teachers' groups' means indicates that there is no significant difference between the two groups.

The number of college science credit hours' mean (11.8) for prospective teachers, which is lower than that of science majors (28.3), and the fact that the prospective teachers groups' science courses are less advanced than those taken by science majors might explain the finding that the group of prospective teachers who were early childhood education majors had lower science processes achievement scores. The finding that prospective teachers acquire low science processes skills has been supported by Jaus (1975) and Campbell and Okey (1977). It is interesting to note that, although the quality and quantity of college science experience for both prospective teachers' groups is almost the same (which might explain why they are not significantly different), the science majors group failed to be significantly superior to the prospective teachers who were intermediate education majors while it was significantly superior to the other.

<u>Differences Between Groups Due to Their Logical Thinking Abilities Scores</u>

Comparison of logical thinking abilities' mean score of 5.82 for the group of prospective teachers who were intermediate majors with the TOLT mean score of 4.92 for the group of prospective teachers who were early childhood education majors and the TOLT mean score of 7.04 for the college science majors group revealed that prospective teachers intermediate-education group was not significantly different from either other group. However, comparison of the college science majors' group's logical thinking abilities with those of prospective teachers who were early childhood education majors revealed that the college science majors were significantly superior in their logical thinking abilities. This finding might have two interpretations: first, it might be possible that those who are superior in their logical thinking abilities chose to specialize in science; second, it might be possible that specializing in college science helped the college science majors to be superior in their logical thinking abilities. However, the study by Wait (1975) who found that undergraduate science majors are superior in their cognitive abilities to undergraduate nonscience majors, and the finding by Kolodiy (1975) that senior college science majors are superior to college freshmen in their cognitive abilities, indicate that the findings of both studies are in agreement with the finding of this study. But the finding of no significant difference in cognitive abilities between college freshman science and nonscience majors by Dunlop and Fazio (1976) was in conflict with this study's findings. The fact that the science majors' group has a higher SAT mean score than both prospective teachers groups' SAT mean scores is an indication of science majors being more able even before taking college science courses. The finding that the science majors' group failed to be significantly superior to the nonscience majors--the prospective teachers' (intermediate education group--made it difficult without more information on science and nonscience majors to make a generalization regarding the superiority of college science majors in their cognitive abilities.

Several studies, including the one by Schwebel (1972), indicating that males have a significantly higher score on Piaget-type tests than females, and the fact that college science groups in this study are 48% males while the group of prospective teachers who were early childhood education majors was 100% female, led the researcher to a possible conclusion that sex factors may contribute to the apparent difference in cognitive abilities between the science and nonscience majors in this study. This possibility is in addition to the combination of both possibilities that being a science major developed superior cognitive abilities and that those who have higher cognitive abilities choose to be science majors.

Variables in College Students' Background that Correlate with and are Useful in Predicting Their Science Processes Achievement Scores

Based on correlation and simple regression analysis of the data, TOLT, SAT, GPA, and college and high school science were significantly related to science process achievement within college students (overall sample subjects). Regressing each of the independent variables independently on TOSP in a simple regression analysis resulted in TOLT, SAT, GPA, and college and high school science as significant predictors of science processes achievement. Age and college mathematics failed to be significantly related to nor to significantly predict science processes achievement. The finding that the highest and most significant relationship between logical thinking abilities as measured by TOLT and science processes achievement as measured by TOSP was expected, given the similarities in thought skills and steps required by both. According to Padilla et al. (1981) science processes skills--formulating hypotheses, designing an experiment, collecting data, and making a generalization--required to conduct experiments are the same steps needed to identify and control variables, which is one of the notions or schemas of formal operational thought.

This finding is in agreement with that of Lawson et al. (1975). Using the Wisconsin Inventory of Science Processes (WISP) and a Piaget-type test, Lawson found that science processes achievement significantly correlated with logical thinking abilities with prospective teachers. Padilla et al.'s (1981) finding that science processes achievement significantly related to logical thinking abilities within both high school and college students is also in agreement with the findings of this study. The findings of this study and other cited studies seem to suggest that logical thinking ability is a significant predictor of science processes achievement.

Although aptitude tests, such as SAT, have been found to be related to college science achievement (Butts, 1981), this study found that SAT scores' relation to science processes achievement needs further evidence before any interpretation or conclusion can be reached regarding the nature of this relationship.

The significant but low correlation between science experience and science processes achievement, especially college science experience, is unexpected, because college science experience is supposed to provide the college student with opportunity to learn and practice the science processes skills through learning of facts, theories and concepts of science, as well as the skills needed to solve science problems and conduct laboratory experiments. It is evident in light of this that lack of inquiry practice in college science teaching (McKinnon & Renner, 1971) might contribute to college science's being a low predictor of science processes achievement in college students.

The stepwise multiple regression analysis identified TOLT, SAT, and GPA in combination as the best prediction model of TOSP within college students. The variables together explained 41.81% of variability in science processes achievement scores within college student groups (overall sample subjects). TOLT was the best predictor; it alone accounted for 36.21% of variability. SAT was the second-best predictor followed by GPA as shown in rank order contributions (Table 15).

The stepwise analysis also indicated that college and high school experience, college mathematics experience, and age were not significant predictors when considered with TOLT, SAT, and GPA.

It is also evident that although college and high school science experiences have had a significant but weak relationship with science processes achievement, both variables failed to be significant predictors when entered with other variables in the stepwise multiple regression analysis.

Variables in Prospective Teachers' Background that Correlate with and Are Useful in Predicting Science Processes Achievement Scores

The correlation and simple regression analyses of the data related to both groups of prospective teachers revealed that TOLT, SAT, and GPA are significantly related to and significant predictors of science processes achievement scores within prospective teachers when entered independently. The data analysis also indicated that college and high school science experience, college mathematics experience, and age are not related to science processes achievement. The finding that TOLT and SAT were related to science processes achievement withinprospective teachers was similar to that which related to the college students overall.

The low and insignificant correlation between science experience and science processes within prospective teachers may be attributed to the low variability in number of credit hours taken by prospective teachers. It is probable that students in the same majors would be required to take almost the same number of science courses.

The stepwise multiple regression analysis regressing all the independent variables on the dependent variables, revealed that only TOLT and SAT were significant predictors. When considered with the other variables, TOLT and SAT constituted the best prediction model for science processes achievement scores within prospective teachers. Both variables combined explained 27.33% of the variability in TOSP. TOLT was the best predictor, alone accounting for 22.91% of variability, while SAT, the second best predictor, improved the predictability of the model from 22.92% to 27.33%.

Although correlation analysis showed that GPA had a significant but weak relationship, stepwise analysis indicated that GPA was not a significant predictor when it was considered with TOLT and SAT. It is obvious that while TOLT and SAT were significant predictors of science processes achievement with prospective teachers, TPA, science and mathematics experience, and age were not significant predictors of such skills.

Variables in College Science Majors' Background that Correlate with and Are Useful in Predicting Science Processes Achievement Scores

The correlation and simple regression analyses of the data related to college science majors resulted in TOLT and GPA being significantly related to science processes achievement, with SAT, college and high school science experience, college mathematics experience, and age not related to science processes achievement within college science majors. Although SAT was related to science processes achievement within overall college students and prospective teachers, it was not related to science processes skills within college science majors.

The stepwise multiple regression analysis identified TOLT as the best predictor of science processes within college science majors. All other variables entered with TOLT were identified to be nonsignificant predictors. TOLT alone constituted the best prediction model, and accounted for 55.36% of variability in science processes achievement within college science majors. Therefore, logical thinking abilities can be used to predict science processes skills within this group.

Summary and Conclusions

This study was designed to investigate the relationship between science processes achievement and the following variables: logical thinking abilities (TOLT), experience in science and mathematics, age, grade point average (GPA), and SAT scores, within groups of prospective teachers and college science majors. The differences and similarities among groups of college students in their science processes achievement and logical thinking ability were also investigated.

Data on the dependent and independent variables related to the 85 sample subjects (37 early childhood education majors, 23 intermediate education majors, 25 college science majors) were gathered and subjected to several statistical analysis techniques by the researcher. Based on the findings of this study, the following conclusions, which are limited to the subjects who participated in this investigation, seem to be appropriate:

1. Among the independent variables (logical thinking abilities, college and high school science experience, college mathematics experience, SAT scores, grade point average (GPA) and age), logical thinking abilities as measured by the TOLT test was the most highly correlated with and the most significant predictor of science processes achievement within prospective teachers, college science majors, and within the college-student sample as a whole. College mathematics and age were not related to science processes achievement in any of these groups.

2. Among college students (overall-sample subjects), the science processes achievement was significantly and

moderately related to logical thinking abilities and SAT scores. It also had statistically significant but low correlation with GPA and college and high school science experience.

3. Among college students, there was no significant relationship between science processes achievement and college mathematics experience and age.

4. Logical thinking abilities, SAT score, Grade Point Average (GPA), in that order, were the best predictors of science processes achievement. The three variables together represent the best prediction model for science processes achievement within college students.

5. Among both prospective teachers' groups, science processes achievement was related significantly to logical thinking abilities and SAT scores. It also had a significant but low correlation with Grade Point Average (GPA).

Among prospective teachers, there was no significant relationship between science processes achievement and any of the remaining variables: college and high school science experience, college mathematics experience, and age.

7. Logical thinking abilities and SAT scores, in that order, were the best significant predictors of science processes achievement. Both variables together represent the best prediction model of science processes achievement within prospective teachers.

8. The science processes achievement of the college science majors' group was significantly and highly related to logical thinking abilities and Grade Point Average (GPA).

9. Within the college science majors' group college and high school science experience, college mathematics experience, SAT scores, GPA, and age were not significantly related to science processes achievement skills.

10. Among the independent variables investigated in this study, logical thinking abilities was the best predictor of science processes achievement among college science majors. It was the only variable included in the best prediction model of science processes achievement among college science majors.

11. The college science majors were significantly superior in their ability to use science processes skills to the group of prospective teachers who were early childhood education majors. However, they were not significantly better than prospective teachers who were intermediate education majors.

12. There was no significant difference between prospective teachers who were early childhood education majors and prospective teachers who were intermediate education majors in their science processes skills.

13. The college science majors had a significantly higher cognitive ability as measured by TOLT than

prospective teachers who were early childhood education majors, but they were not significantly superior to the prospective teachers who were intermediate education majors.

14. There was no significant difference between the two groups of prospective teachers--early childhood education majors--and intermediate education majors in their logical thinking abilities as measured by TOLT.

Recommendations for Further Research

Based on the findings and conclusions of this study, the following suggestions for further research seem to be appropriate:

1. For better understanding of the nature of the relationship between science processes skills and logical thinking abilities and other variables such as those investigated in this study, the investigator suggests that a follow-up study on the same sample subjects be carried out after their graduation. Such a study should investigate whether the findings of this study still hold. Also, a follow-up study of the prospective teachers' group after a period of in-service would help to shed some light on the effect of teaching experience on science processes skills.

2. The fact that the three most significant predictors of science processes skills within college students had been able to account for only 41% of the variability in such skills suggests that the method of this study might

be used with a larger and more balanced sample size, from the same as well as different populations, and with additional independent variables, such as sex and social background. These, among many others, might be useful in explaining the unaccounted-for variability (59%) in this study.

3. Based on the finding of this study and other studies cited that science processes skills are highly related to cognitive abilities, it is suggested that the two variables might affect or cause each other; therefore, an experimental study might be helpful to determine whether an increase in one could affect the other, as suggested by Padilla et al. (1981).

4. Since the college science majors' group seemed to have better science processes skills than prospective teachers did, a study should be designed to investigate what accounted for such difference between the two groups, by answering the following questions: Is it the quantity of science experience? Is it the quality of science experience? Is it the initial difference in the logical thinking abilities of the subject? Or, is it the combination of any two or three of these variables?

5. The finding that prospective teachers' college science experience was not related to science processes, and the conclusion made by Jaus (1975) that preservice teachers might not acquiry inquiry skills as a result of

their preservice training indicates that prospective teachers' college science courses' content and teaching practice should be examined to identify their weaknesses and to determine what can be done to provide the prospective teachers with more competence in the science processes skills.

6. In light of the fact that college mathematics requires abstract and higher cognitive abilities, and the finding that science processes skills correlate highly with logical thinking abilities, the finding that college mathematics was not related to science processes skills suggests that a study with a subject sample that includes a wide range of mathematics experience and achievement will be useful in detecting the effect of mathematics experience on the science processes skills.

Implications

Implications for Science Education

The development of inquiry and problem-solving skills is viewed as an essential outcome of science education. However, the evidence from the literature indicates that this goal is still unfulfilled in spite of some efforts through innovative programs, improved equipment and facilities, and better trained teachers (Welch et al., 1981). The lack of inquiry practice in college science teaching McKinnon & Renner, 1971) and the indication that a majority of young adults are not functioning at the formal level of thinking which is required in learning science concepts and processes taught in high school and college science courses (Chiappetta, 1976) are cited in the literature (McKinnon & Renner, 1971) as contributing factors for inquiry skill deficiency and lack of intellectual development among college as well as below-college-level students.

The fact that among the sample subjects of this study, the college science majors' group is able to think logically better than the prospective teachers' group, and the wide range of the sample subjects' performance on logical thinking abilities measure (TOLT), and SAT scores, suggest, as indicated by Chiappetta (1976) and Kolodiy (1977), that there is a wide range of variability in the cognitive functioning of college students. Furthermore, the finding of this study that logical thinking abilities as measured by TOLT are highly correlated with and are the best predictor of science processes skills as measured by TOSP among college students, seem to support the argument that while most science subjects require abstract thinking abilities to learn science concepts and processes, there is a lack of such abilities among large portions of college students. The traditional lecture-based teaching technique confronts students with concepts and processes in a way that leads them to meaningless rote learning.

Schwebel (1972) referring to the problems of the mismatch between students' cognitive abilities and the subject matter, put it this way:

> A college student must resort to memory, that is to meaningless memorization of conclusions and process and to meaningless memorization of problem-solving methods which can then be applied only in rote fashion to familiar problems (p. 22). (Cited by Kolodiy, 1977)

Kolodiy (1974) dealt with the effect of teaching technique on college science teaching, stating:

> Present teaching techniques might be reaching fewer than half our students. All that students are learning, apparently, is the ability to parrot back materials for the purpose of attaining passing grades without learning any concepts involved. (p. 262)

Based on these statements and the findings of this study, the implications for better and more efficient science teaching and learning are 1) that the level of students' cognitive functioning should be assessed and the educational experience be planned and presented to the students accordingly, with more attention given to individual differences; 2) that traditional teaching practice based on lecture method alone be recognized as not an effective teaching technique for all subjects at all times. A better alternative for more effective educational experience and more meaningful learning would be a combination of "listening, talking and thinking" (Kolodiy, 1977) through the inquiry discovery approach which provides the students with opportunities to manipulate and interact with the material, as well as among themselves and their teacher, as implied in Piaget theory.

Implication for Teacher Training

Most of the current elementary and secondary science education programs are designed to insure the balance between concepts and processes, through inquiry-discovery teaching-learning practice. The main objective of these programs was to help the students acquire the basic science knowledge and skills of problem-solving as well as offering them the opportunity to grow and develop their potential and become scientifically literate.

In spite of the evidence from the literature (Renner et al., 1973; Raun & Butts, 1967; Scott, 1970) that such a program is an effective means for promoting intellectual abilities and scientific literacy, especially when introduced to elementary and secondary-level students through the inquiry-discovery approach, the evidence from the literature unfortunately indicated that secondary and elementary teachers fail to use the inquiry-discovery approach in their teaching practice (McKinnon & Renner, 1971; Brandwein, 1968). Deficiency in science processes skills among teachers as a result of lack of inquiry practice in college science teaching and inadequate teacher-training programs are cited as one of the main reasons behind the limited science processes activities by the teachers in the classroom (Leonard, 1969; McKinnon & Renner, 1971).

The finding of this study that prospective teachers (early childhood education majors) with TOSP mean score of 71.59 out of possible 96.00, which is significantly lower than that of college science majors group, and the conclusions made by Jaus (1975) and Campbell and Okey (1977) that prospective teachers receive little training in science process skills through their inservice training programs, suggest that it is possible that prospective teachers might graduate and go on to their teaching professions with deficiency in science processes skills and inability to pass on those skills to their students.

Many researchers, including Jaus (1975) report that "prospective elementary teachers trained in the integrated science processes skills voluntarily select and write significantly more instructional objectives designed to teach these skills to children than do their untrained peers . . ." (p. 445). In light of all this and the fact that achieving the desired state of inquiry skills in the students requires a teacher with high competence in these skills, the implication for teacher-training institutions is that the necessity and importance of learning the science processes skills be recognized. It follows that teacher-training programs have to account for these qualities in their programs and produce teachers who are well trained in the inquiry skills, not only for their future practice but also for their own learning and development. Providing the prospective teachers with hands-on, realistic science experience in which they will be given the opportunity to observe and examine scientific objects, phenomena, or events, learn how to form a problem, state hypotheses, gather, analyze, and interpret data, and practice how to make generalizations, will insure better science concepts and processes learning by the prospective teachers, provided that this experience is suitable to their level of abilities.

It is also important to notice that the development of the science processes skills through science experience might not insure the ability of prospective teachers to use it in classroom practice. It is the responsibility of professional educators, especially those who are responsible for science education courses, to help the future teachers gain the ability to use these skills in their teaching practice.

With the finding that science processes skills are highly related to logical thinking abilities, TOLT or any other similar, valid, and reliable measure might be used to assess prospective teachers' cognitive abilities. TOSP or any similar, valid, and reliable measure, as well as the best prediction model for science processes skills for prospective teachers, might be used to assess or predict prospective teachers' achievements in those skills. The assessment and prediction of prospective teachers' level of cognitive abilities and science processes skills might help set the criteria and guidelines for admittance of placement for diagnostic purposes, at the suitable level of science concepts and processes experiences. The assessment of these skills might also be helpful in setting a standard for the level of competence in these skills that are considered to be essential parts of the graduation requirements.

Efforts to search for better ways to train teachers in science processes and concepts, and efforts to examine the relationships between teachers' level of proficiency in science concepts, processes skills, and cognitive functioning and their effectiveness in the classroom should be a part of the continuous efforts to improve teacher-training programs and the teaching and learning processes.

In the final analysis, if we value and hope that meaningful teaching and learning through inquiry might become a fulfilled dream, then training the teacher through the inquiry discovery approach is a most important step toward the realization of that goal.

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APPENDIX A

TEST OF LOGICAL THINKING AND ITS ANSWER SHEET

Item 1

Orange Juice #1

Four large oranges are squeezed to make six glasses of juice. How much juice can be made from six oranges?

a. 7 glasses
b. 8 glasses
c. 9 glasses
d. 10 glasses
e. other

Reason

1. The number of glasses compared to the number of oranges will always be in the ratio 3 to 2.

2. With more oranges, the difference will be less.

3. The difference in the numbers will always be two.

4. With four oranges the difference was 2. With six oranges the difference would be two more.

5. There is no way of predicting.

Item 2

Orange Juice #2

How many oranges are needed to make 13 glasses of juice?

a. 6 1/2 oranges
b. 8 2/3 oranges
c. 9 oranges
d. 11 oranges
e. other

Reasons

1. The number of oranges compared to the number of glasses will always be in the ratio 2 to 3.

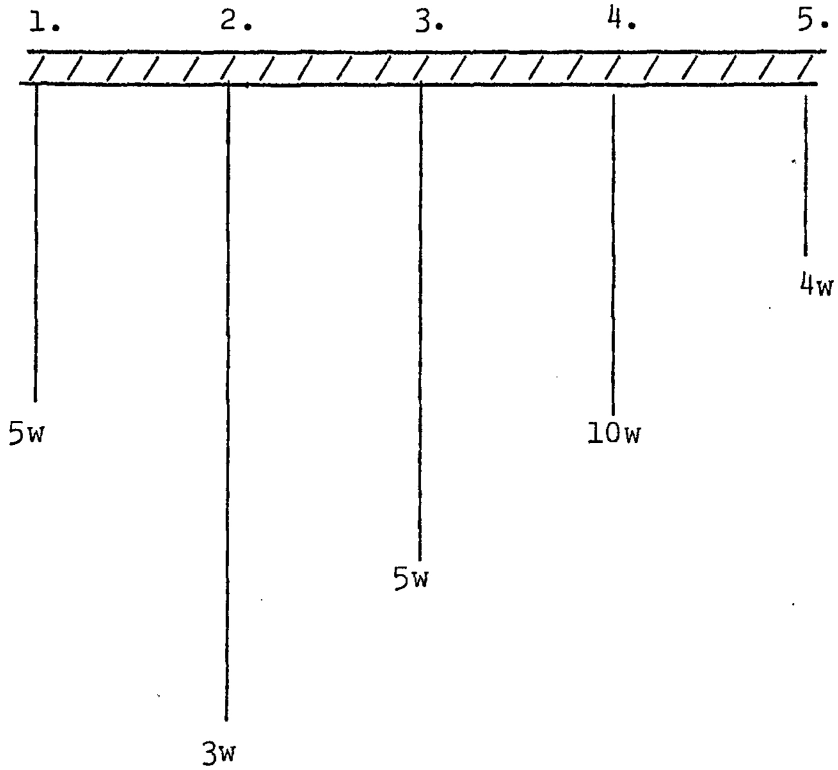
2. If there are seven more glasses, then five more oranges are needed.

3. The difference in the numbers will always be two.

4. The number of oranges will be half the number of glasses.

5. There is no way of predicting the number of oranges.

Item 3 The Pendulum's Length



Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4
b. 2 and 4
c. 1 and 3
d. 2 and 5
e. all

<u>Reason</u>

1. The longest pendulum should be tested against the shortest pendulum.

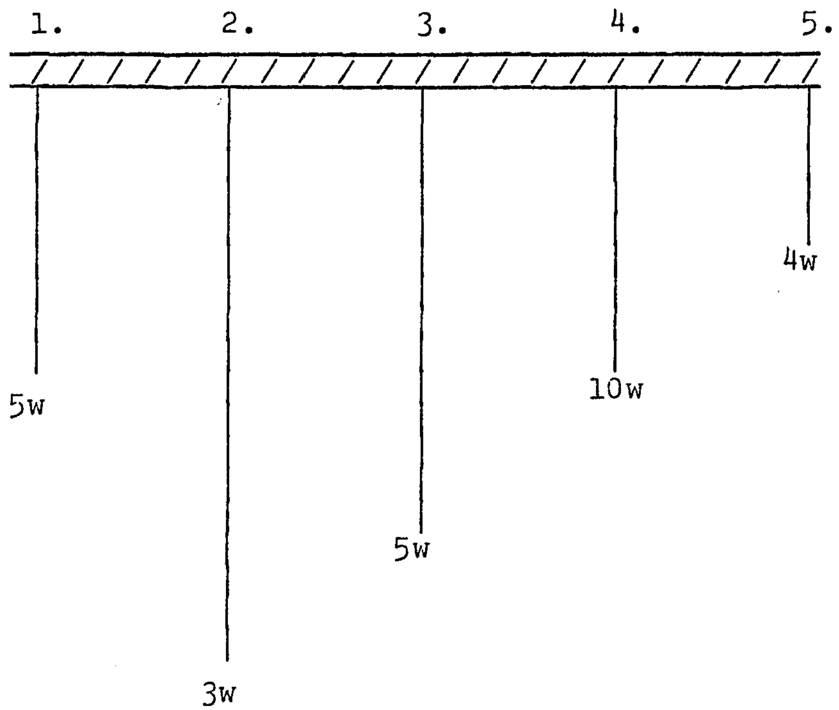
2. All pendulums need to be tested against one another.

3. As the length is increased the number of washers should be decreased.

4. The pendulums should be the same length but the number of washers should be different.

5. The pendulums should be different lengths but the number of washers should be the same.

Item 4 The Pendulum's Weight



Suppose you wanted to do an experiment to find out if changing the weight on the end of the string changed the amount of time the pendulum takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4
b. 2 and 4
c. 1 and 3
d. 2 and 5
e. all

<u>Reason</u>

1. The heaviest weight should be compared to the lightest weight.

2. All pendulums need to be tested against one another.

3. As the number of washers is increased the pendulum should be shortened.

4. The number of washers should be different but the pendulums should be the same length.

5. The number of washers should be the same but the pendulums should be different lengths.

Item 5 The Vegetable Seeds

A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package what are the chances that it is a bean seed?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 4
d. 1 out of 6
e. 4 out of 6

Reasons

1. Four selections are needed because the three squash seeds could have been chosen in a row.

2. There are six seeds from which one bean seed must be chosen.

3. One bean seed needs to be selected from a total of three.

4. One half of the seeds are bean seeds.

5. In addition to a bean seed, three squash seeds could be selected from a total of six.

Item 6 The Flower Seeds

A gardener bought a package of 21 mixed seeds. The package contents listed:

3 short red flowers
4 short yellow flowers
5 short orange flowers
4 tall red flowers
2 tall yellow flowers
3 tall orange flowers.

If just one seed is planted, what are the chances that the plant that grows will have red flowers?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 7
d. 1 out of 21
e. other

Reason

1. One seed has to be chosen from among those that grow red, yellow or orange flowers.

2. 1/4 of the short and 4/9 of the talls are red.

3. It does not matter whether a tall or a short is picked. One red seed needs to be picked from a total of seven red seeds

4. One red seed must be selected from a total of 21 seeds.

5. Seven of the twenty-one seeds will produce red flowers.

Item 7 The Mice

The mice shown represent a sample of mice captured from a part of a field. Are fat mice more likely to have black tails and thin mice more likely to have white tails?

a. Yes

b. No

Reason

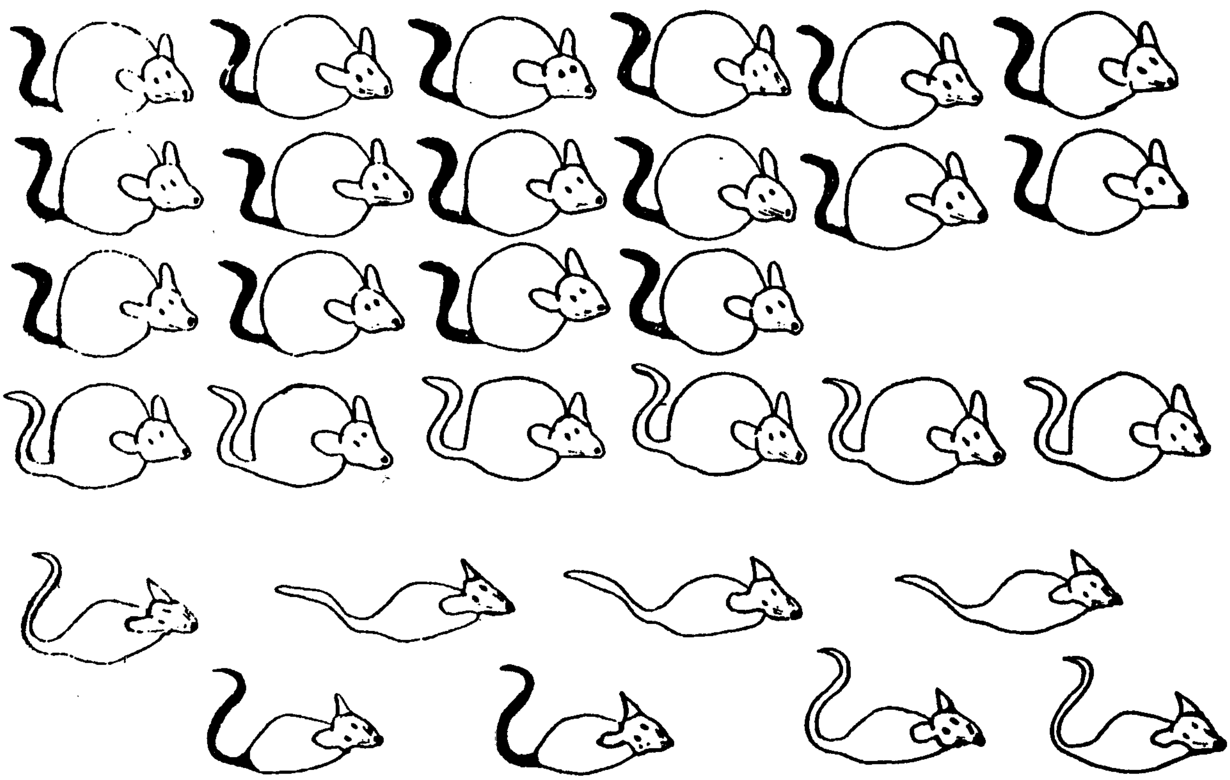
1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails.

2. Some of the fat mice have white tails and some of the thin mice have white tails.

3. 18 mice out of thirty have black tails and 12 have white tails.

4. Not all of the fat mice have black tails and not all of the thin mice have white tails.

5. 5/12 of the white-tailed mice are fat.



Item 8 The Fish

Are fat fish more likely to have broad stripes than thin fish?

a. Yes

b. No

Reason

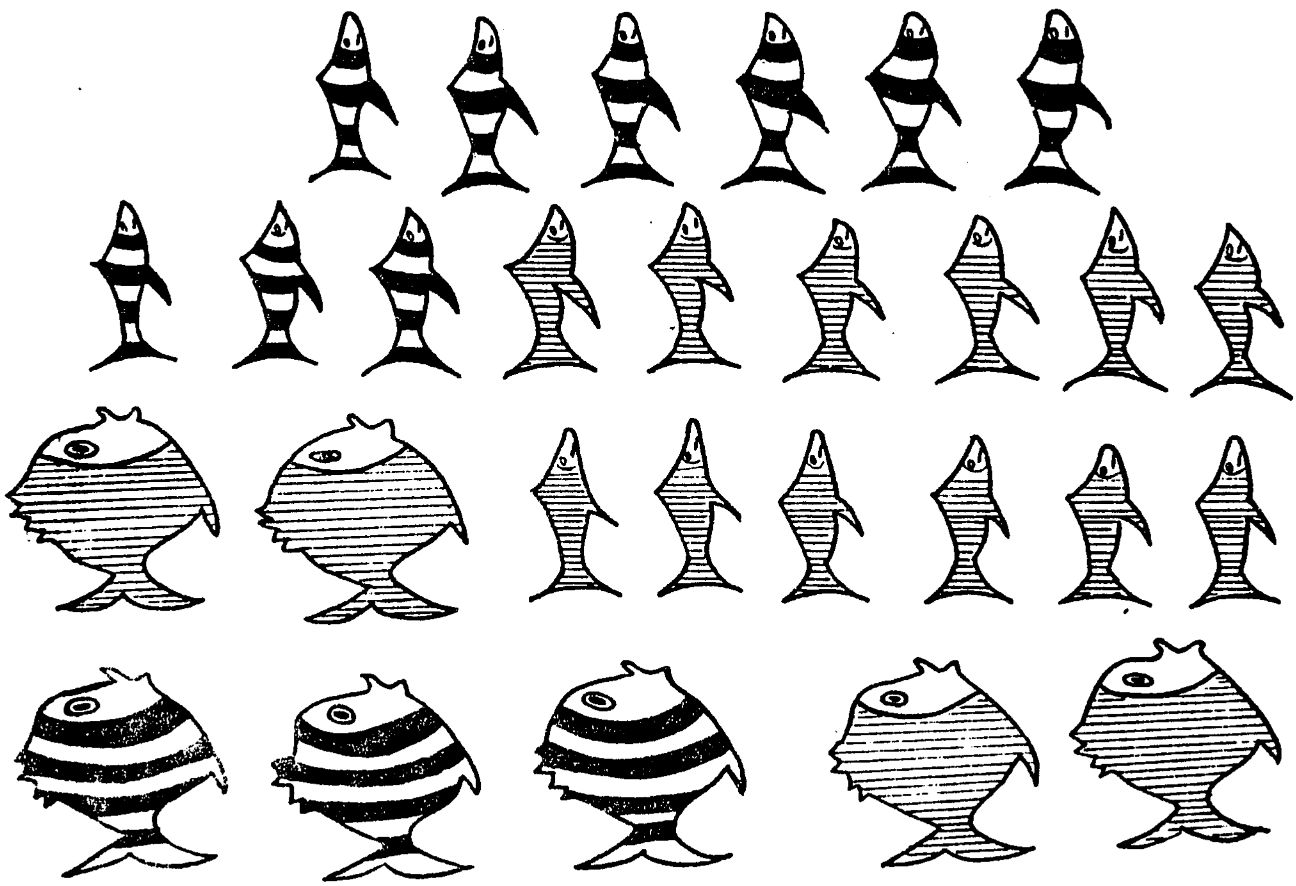
1. Some fat fish have broad stripes and some have narrow stripes.

2. 3/7 of the fat fish have broad stripes.

3. 12/28 are broad striped and 16/28 are narrow striped.

4. 3/7 of the fat fish have broad stripes and 9/21 of the thin fish have broad stripes.

5. Some fish with broad stripes are thin and some are fat.



Item 9 The Student Council

Three students from grades 10, 11, 12 were elected to the student council. A three-member committee is to be formed with one person from each grade. All possible combinations must be considered before a decision can be made. Two possible combinations are Tom, Jerry and Dan (TJD) and Sally, Anne and Martha (SAM). List all other possible combinations in the spaces provided.

More spaces are provided on the Answer Sheet than you will need.

STUDENT COUNCIL

Grade 10	Grade 11	Grade 12
Tom (T)	Jerry (J)	Dan (D)
Sally (S)	Anne (A)	Martha (M)
Bill (B)	Connie (C)	Gwen (G)

Item 10 The Shopping Center

In a new Shopping Center, 4 store locations are going to be opened on the ground level.

A BARBER SHOP (B), a DISCOUNT STORE (D), a GROCERY STORE (G), and a COFFEE SHOP (C) want to move in there. Each one of the stores can choose any one of four locations. One way that the stores could occupy the 4 locations is BDGC. List all other possible ways that the stores can occupy the 4 locations.

More spaces are provided on the Answer Sheet than you will need.

ANSWER SHEET

Social Security #__________
Age__________
Sex__________

Directions

A series of eight problems is presented. Each problem will lead to a question. Record the answer you have chosen and reason for selecting that answer.

Problem	Best Answer	Reason
1.	________	_____
2.	________	_____
3.	________	_____
4.	________	_____
5.	________	_____
6.	________	_____
7.	________	_____
8.	________	_____

Put your answers to questions 9 and 10 below:

9. TJD SAM ____ ____

10. BDGC ____ ____ ____

APPENDIX B

SAMPLE OF THE TEST OF SCIENCE PROCESSES AND ITS ANSWER SHEET

ALL OF THE QUESTIONS ON THIS PAGE REFER TO COLOR PICTURES. YOU SHOULD LOOK AT THE PICTURES AS THE TEACHER SHOWS THEM TO YOU AND THEN ANSWER THE QUESTIONS.

1.
BE SURE YOU ARE USING ANSWER SPACE 1
This is a picture of 5 shirts. Which choice includes only the shirts you would wear if you wanted to be seen easily in the dark?
1. 1 and 4
2. 2 and 3
3. 1, 3, and 5
4. 2, 4, and 5
5. 2, 3, and 5

2.
This is a picture of 8 pieces of paper. Which is the only group of two pieces that you can take away so that you have taken away all of one color and all of one shape?
1. 1 and 6
2. 2 and 8
3. 2 and 7
4. 1 and 3
5. 4 and 5

3.
This is a picture of 5 objects. Which choice is a way they are the <u>same</u>?
1. They are all used for eating.
2. They are all the same color.
3. They are all made of wood.
4. They are all about the same size.
5. They are all about the same shape.

4.
This is a picture of 8 pieces of paper. Which choice includes only the pieces which are red and have a triangular hole?
1. 1, 4, and 6
2. 1, 2, 3, 4, and 6
3. 5 and 8
4. 1, 4, 6, and 8
5. 4 and 6

5.
BE SURE YOU ARE USING ANSWER SPACE 5
Look at the picture of the 8 pieces of paper again. Which choice includes only those pieces that are <u>NOT</u> red and have square holes?
1. 2, 3, 5, and 7
2. 5 and 7
3. 5, 7, and 8
4. 1, 3, 5, 7, and 8
5. 2, 3, 4, and 8

6.
This is a picture of 10 beads. Which is the only group of 3 beads that you can take away so that your three are all one color and none of the 7 you leave is that color?
1. 4, 6, and 7
2. 2, 6, and 8
3. 1, 3, and 5
4. 3, 5, and 10
5. 4, 7, and 9

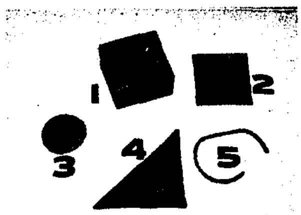
THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN LOOK AT THINGS AND HOW CAREFULLY YOU CAN TELL WHAT YOU SEE.

13.

This is a picture of a boy studying what happens when he tightens or loosens the strings of a guitar. Which one of the following is <u>most</u> important to his study?

1. The lengths and thicknesses of the strings
2. The size of the guitar
3. The temperature of the strings
4. What the guitar and strings are made of
5. The age of the guitar

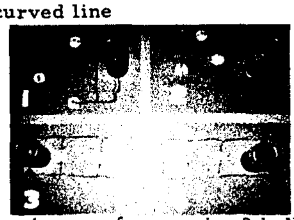
14.



This is a picture of 5 things. Which of them has <u>volume</u>?

1. The block
2. The square
3. The circle
4. The triangle
5. The curved line

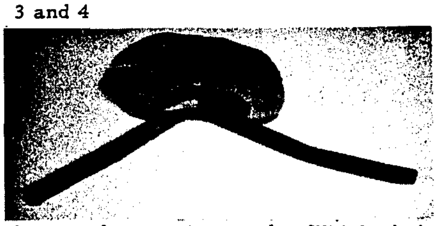
15.



This picture shows 4 ways of arranging 3 bulbs and a battery. Which two ways are the same?

1. 1 and 4
2. 2 and 4
3. 1 and 2
4. 3 and 2
5. 3 and 4

16.

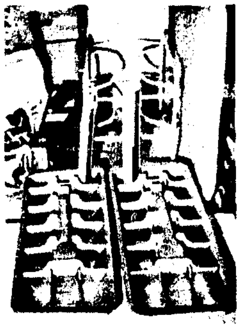


This is a picture of a growing seed. Which choice best describes what you <u>see</u>?

1. The seed is growing.
2. Someone planted and watered the seed.
3. The seed coat has split and a root and a stem are coming out of the seed.
4. A root is growing down and a stem is growing up.
5. The seed has germinated.

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN PLAN AND UNDERSTAND EXPERIMENTS.

67.



This is a picture of two ice cube trays. One is filled with very hot water and one with cold water. Many people say: "HOT WATER MAKES ICE CUBES QUICKER THAN COLD WATER." Which choice would be the best statement for helping you plan an experiment to test this?

1. The hotter the water you start with, the faster it will freeze into ice cubes.
2. Hot water freezes into ice cubes fast.
3. Hot water freezes at higher temperatures than cold water.
4. Hot water freezes into ice cubes faster because it turns on the refrigerator.
5. Hot water makes steam which keeps the refrigerator going.

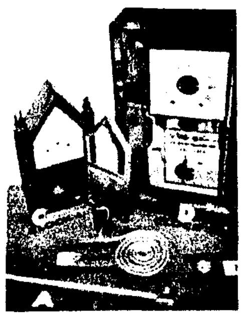
68.
If you wanted to test the statement you chose in the last question, which factor listed below is the only one you should allow to change during the experiment?

1. The temperature of the water you use.
2. The amount of water in each tray.
3. The position of the trays in the freezer.
4. The refrigerator in which you put the trays.
5. The kind of trays you use.

69.
Some things that can change during your experiment are listed below. Which one changes because of all the others?

1. The kind of trays you use.
2. The refrigerator in which you put the trays.
3. The time it takes for freezing.
4. The temperature of the water you use.
5. The amount of water in each tray.

70.

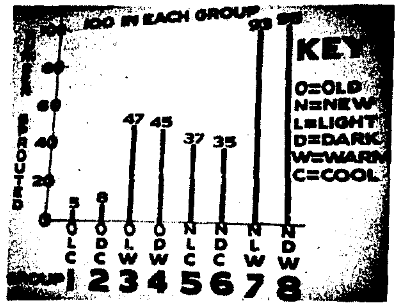


BE SURE YOU ARE USING ANSWER SPACE 70

This is a picture of 5 objects. If you want to study the relationship between the length of a pendulum and how long it takes to complete one swing, which things would be best to use?

1. C and D only
2. A, B, and E only
3. A, C, and D only
4. A and B only
5. All of the things

71.



This is a graph of the results of an experiment. 400 seeds that were 10 years old and 400 new seeds were planted in good soil and watered each day.
100 old seeds and 100 new seeds were put in a dark cool place.
100 old seeds and 100 new seeds were put in a light cool place.
100 old seeds and 100 new seeds were put in a dark warm place.
100 old seeds and 100 new seeds were put in a light warm place.

Five things which may affect the growth of seeds are: water, heat, soil, age, and light. Which of these were tested?

1. Heat, age, and light only
2. Soil, heat, and light only
3. Heat, soil, age, and light only
4. Water and soil only
5. Water and age only

72.
Look at the graph again. Here are some things you can see on the graph:
A. 365 seeds sprouted.
B. 400 seeds were 10 years old.
C. 400 seeds were new.
D. 400 seeds were kept cool.
E. 400 seeds were kept warm.
F. 400 seeds were kept in the light.
G. 400 seeds were kept in the dark.
Which one happened because of all the others?

1. A
2. B
3. D
4. F
5. G

73.
Look at the graph once more. Here are 5 statements about this experiment:
A. More new seeds sprout than old seeds.
B. Heat makes a difference in how many seeds sprout.
C. Light makes a difference in how many seeds sprout.
D. Water does not make a difference in how many seeds sprout.
E. Light does not make a difference in how many seeds sprout.
Which of these can you find from the graph?

1. A only
2. A, B, and D only
3. D and E only
4. C and D only
5. A, B, and E only

74.
Look at the graph again. Listed below are some other experiments you could do. Which one is <u>NOT</u> based on the experiment shown in the graph?

1. A study of seeds of several ages.
2. A study of the effect of different numbers of hours of light and dark on seeds.
3. A study of the heights of plants.
4. A study of the effect of different amounts of water on seeds.
5. A study of the effect of different temperatures on seeds.

TOSP ANSWER SHEET

Circle the answer.

Social Security No. ________
Age ________
Sex ________

1.	1	2	3	4	5	26.	1	2	3	4	5
2.	1	2	3	4	5	27.	1	2	3	4	5
3.	1	2	3	4	5	28.	1	2	3	4	5
4.	1	2	3	4	5	29.	1	2	3	4	5
5.	1	2	3	4	5	30.	1	2	3	4	5
6.	1	2	3	4	5	31	1	2	3	4	5
7.	1	2	3	4	5	32	1	2	3	4	5
8.	1	2	3	4	5	33.	1	2	3	4	5
9.	1	2	3	4	5	34.	1	2	3	4	5
10.	1	2	3	4	5	35.	1	2	3	4	5
11.	1	2	3	4	5	36.	1	2	3	4	5
12.	1	2	3	4	5	37.	1	2	3	4	5
13.	1	2	3	4	5	38.	1	2	3	4	5
14.	1	2	3	4	5	39.	1	2	3	4	5
15.	1	2	3	4	5	40.	1	2	3	4	5
16.	1	2	3	4	5	41.	1	2	3	4	5
17.	1	2	3	4	5	42.	1	2	3	4	5
18.	1	2	3	4	5	43.	1	2	3	4	5
19.	1	2	3	4	5	44.	1	2	3	4	5
20.	1	2	3	4	5	45.	1	2	3	4	5
21.	1	2	3	4	5	46.	1	2	3	4	5
22.	1	2	3	4	5	47.	1	2	3	4	5
23.	1	2	3	4	5	48.	1	2	3	4	5
24.	1	2	3	4	5	49.	1	2	3	4	5
25.	1	2	3	4	5	50.	1	2	3	4	5

51.	1	2	3	4	5	76.	1	2	3	4	5
52.	1	2	3	4	5	77.	1	2	3	4	5
53.	1	2	3	4	5	78.	1	2	3	4	5
54.	1	2	3	4	5	79.	1	2	3	4	5
55.	1	2	3	4	5	80.	1	2	3	4	5
56.	1	2	3	4	5	81.	1	2	3	4	5
57.	1	2	3	4	5	82.	1	2	3	4	5
58.	1	2	3	4	5	83.	1	2	3	4	5
59.	1	2	3	4	5	84.	1	2	3	4	5
60.	1	2	3	4	5	85.	1	2	3	4	5
61.	1	2	3	4	5	86.	1	2	3	4	5
62.	1	2	3	4	5	87.	1	2	3	4	5
63.	1	2	3	4	5	88.	1	2	3	4	5
64.	1	2	3	4	5	89.	1	2	3	4	5
65.	1	2	3	4	5	90.	1	2	3	4	5
66.	1	2	3	4	5	91.	1	2	3	4	5
67.	1	2	3	4	5	92.	1	2	3	4	5
68.	1	2	3	4	5	93.	1	2	3	4	5
69.	1	2	3	4	5	94.	1	2	3	4	5
70.	1	2	3	4	5	95.	1	2	3	4	5
71.	1	2	3	4	5	96.	1	2	3	4	5
72.	1	2	3	4	5	97.	1	2	3	4	5
73.	1	2	3	4	5	98.	1	2	3	4	5
74.	1	2	3	4	5	99.	1	2	3	4	5
75.	1	2	3	4	5	100.	1	2	3	4	5

APPENDIX C

RAW SCORES

Table A

Raw Scores Table

Subject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOSP
Prospective Teachers (Intermediate Education Majors)									
1	1	810	2.0	276	2.50	14	6	5	71
2	1	900	2.0	252	2.36	10	12	7	74
3	1	750	3.0	250	3.60	12	6	5	66
4	1	1160	4.0	276	3.75	13	6	9	78
5	1	840	3.0	253	2.77	14	9	2	66
6	1	1180	3.0	252	3.59	14	6	8	79
7	1	840	4.0	276	3.26	14	15	4	82
8	1	880	3.0	249	3.14	10	16	6	71
9	1	890	3.0	256	2.86	14	6	9	79
10	1	970	2.0	250	3.32	14	9	7	78
11	1	998	2.0	406	3.87	12	6	5	81
12	1	680	1.0	248	3.99	8	7	5	82
13	1	890	2.00	245	2.70	14	9	9	77

Table A (continued)

Sub-ject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOSP
	Prospective Teachers (Intermediate Education Majors) (continued)								
14	1		2.0	444	3.18	10	6	8	86
15	1	890	3.0	252	3.35	14	6	4	68
16	1	750	1.0	318	2.46	9	6	6	78
17	1	650	3.0	247	1.89	6	9	2	58
18	1	660	3.0	235	3.32	10	6	3	61
19	1	1070	4.0	259	2.52	20	6	8	81
20	1	850	2.0	269	3.64	24	6	5	76
21	1		2.0	262	2.38	11	10		59
22	1	1110	2.0	261	2.59	14	6	5	86
23	1	1160	2.3	257	2.79	10	9	6	64

Table A (continued)

Subject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOSP
Prospective Teachers (Early Childhood Education Majors)									
24	2	870	3.0	235	2.30	9	6	3	72
25	2	920	2.0	253	2.65	6	3	9	54
26	2	740	4.0	270	3.13	12	6	4	67
27	2	710	4.0	253	3.13	15	7	2	75
28	2	870	2.0	249	2.74	6	9	6	76
29	2	880	4.0	259	2.48	17	6	2	82
30	2	1080	2.0	256	3.61	7	9	9	77
31	2		1.0	260	2.28	17	9	2	70
32	2	750	3.0	269	3.80	14	9	8	72
33	2	550	2.0	248	2.63	14	9	5	64
34	2		1.0	353	3.83	7	6	2	73
35	2	850	1.5	266	2.78	7	6	2	65

Table A (continued)

Sub-ject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOSP
	Prospective Teachers (Early Childhood Education Majors) (continued)								
36	2	870	1.5	271	3.00	8	3	4	77
37	2	950	2.0	295	4.00	9	6	9	79
38	2	900	2.0	235	2.42	10	6	2	67
39	2	500	2.0	299	2.10	10	6	1	58
40	2	870	4.0	256	2.66	14	6	5	74
41	2	690	3.0	243	1.87		9	7	66
42	2		2.0	260	3.66	9	6	7	78
43	2	780	3.0	268	2.60	19	9	8	78
44	2	590	1.0	251	3.14	15	6	3	58
45	2	890	2.3	246	3.33	6	3	5	74
46	2	770	2.0	276	3.20	11	9	8	82
47	2		1.0	462	4.00	17	6	6	77
48	2	870	4.0	250	2.75	14	9	5	80
49	2	730	3.0	269	3.46	7	6	1	81

Table A (continued)

Sub-ject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOST
	Prospective Teachers (Early Childhood Education Majors)(continued)								
50	2	790	3.0	248	3.41	14	6	3	61
51	2	560	1.5	301	3.55	17	6	1	63
52	2	940	4.0	261	2.89	22	6	9	81
53	2	830	3.0	257	2.23	14	6	1	67
54	2	910	2.0	248	2.58	14	6	7	71
55	2	840	2.0	257	3.47	10	6	6	74
56	2	980	3.0	253	3.72	10	9	8	77
57	2	.	3.0	378	3.09	7	6	5	55
58	2	1118	2.0	268	2.30	21	9	1	57
59	2	1060	4.0	249	3.86	7	6	8	86
60	2	1150	2.0	2.45	2.97	11	3	8	81

Table A (continued)

Sub-ject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOSP
				College Science Majors					
61	3	810	4.0	252	2.43	39	9	6	66
62	3	600	2.5	276	2.40	20	6	9	75
63	3	940	3.0	262	2.49	54	6	8	74
64	3	950	3.0	236	3.16	8	9	5	65
65	3	1300	3.0	246	2.72	22	9	3	66
66	3	990	4.0	238	3.70	12	12	7	85
67	3	910	4.0	236	1.92	16	9	4	74
68	3	1200	4.0	254	3.30	45	9	10	85
69	3	1170	3.0	240	3.93	11	3	10	85
70	3	1020	3.0	263	2.66	46	3	6	71
71	3	900	3.0	242	3.01	19	9	4	72
72	3	910	3.0	246	2.17	22	6	3	79
73	3	820	5.0	243	2.04	17	6	1	67

Table A (continued)

Subject	Group	SAT	HS SCI	Age	GPA	COLL SCI	COLL MATH	TOLT	Tot. TOSP
				College Science Majors (continued)					
74	3	600	2.5	311	3.85	36	12	9	87
75	3	920	3.0	247	3.95	43	15	8	84
76	3	930	4.0	244	2.96	23	15	10	83
77	3	990	2.0	284	2.38	28	8	5	79
78	3	960	3.0	268	2.36	53	11	9	80
79	3	950	4.0	358	2.86	19	12	9	83
80	3	1160	3.0	332	3.93	19	12	10	83
81	3	1110	4.0	357	2.00	20	12	6	76
82	3	1350	4.0	245	4.00	27	9	10	92
83	3	1140	4.0	247	3.72	25	6	5	72
84	3	1410	3.0	310	3.57	32	6	10	92
85	3	1360	4.0	283	2.71	53	11	9	78