The effects of learning styles on the science process work of middle school students
by Walter Harold Woolbaugh

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Education
Montana State University

Abstract:
This study examined the effects of middle school students' learning styles in working with process lab science. The results of lab partners of different and similar learning styles working together were also considered.

The lab learning styles of the students were identified and classified into three types. These three types were compared with each other as to their performance on lab process skills, creativity tests, classroom grades and standardized tests.

It was found that Type I students recorded higher achievement on classroom grades and lower achievement on creativity ratings. The Type II students recorded lower classroom grades and higher creativity ratings. Both Type I and Type II students scored comparatively high on standardized tests. Type III students performed within the average scores in all areas. There was not any relationship found between learning style and lab process achievement. The learning style of the lab partner did not matter with the Type I and Type II students, but the Type III students preferred to choose their partners, and their lab performance was higher when allowed this choice.

It is recommended that educators use learning style information to educate themselves and their students as to individual strengths, weaknesses and preferences. Learning style information is beneficial when selecting lab partners to work on science labs.

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ABSTRACT

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It was found that Type I students recorded higher achievement on classroom grades and lower achievement on creativity ratings. The Type II students recorded lower classroom grades and higher creativity ratings. Both Type I and Type II students scored comparatively high on standardized tests. Type III students performed within the average scores in all areas. There was not any relationship found between learning style and lab process achievement. The learning style of the lab partner did not matter with the Type I and Type II students, but the Type III students preferred to choose their partners, and their lab performance was higher when allowed this choice.

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CHAPTER I

INTRODUCTION

BACKGROUND

Some students perform better in classes where they are allowed to explore and experiment, and other students perform better in classes where information is presented in an organized lecture approach. Sometimes students enjoy working on their own projects with the grading scale dependent on their ability to create and explore. When these students are given "cookbook" type activities, they go off to explore their own possibilities for other types of activities. They do not want to attempt what has already been done, but would rather develop something new.

Other students perform better in classes where the approach is very objective and direct. The teacher tells the student exactly what is expected, the student performs according to expectations, receives a grade and goes on to the next task. This type of student sometimes likes things direct and to the point. Students seldom fit neatly into the categories researchers design for them, and yet there are students who have tendencies and preferences towards different types of activities.

Science teachers should be concerned with students' knowledge and with students' ability to explore and make discoveries in new areas. Exploration is the heart of science and scientific inquiry (Chang, 1988). Teachers attempt to create in their students the desire to explore and inquire about their environment.

Research shows that students learn more and retain the material longer when they first have a chance to explore the material(Renner, Abraham, & Birnie, 1988). Relatively open-ended investigations are sometimes called "exploratory labs."

Teachers and students labor long hours over exploratory lab science. Teachers labor over the creation and evaluation of such activities, and students labor over completion of these labs. Some students seem intuitively able to handle these labs without any problem, and other students experience difficulties. What factors would lead some students to do well with these types of activities, and what could be done to strengthen exploratory science lab work?

Teachers working with science lab students quickly realize that some students have an easier time in science lab. Although some students can learn to function comfortably and effectively in a laboratory, others are successful when science is presented other ways. Can this "lab type" be identified, and characterized for the student and teacher?

Students learn differently and teachers teach differently. To what degree does student learning style affect students' learning exploratory labs, and to what extent should teachers adjust their instructional plans accordingly?

STATEMENT OF PROBLEM

Identify the lab learning characteristics for given types of science lab students, and using this knowledge, help students to perform better and feel more comfortable during process science labs. The knowledge would also be used to help instructors design better process labs.

The steps involved in this study were:

(1) Through preference instruments and observation, to study learning styles in science lab students.

(2) Use this information to construct a Science Lab Learning Style Inventory. This inventory will assess the science lab learning styles of the students.

(3) Analyze students' abilities and preferences relating to process science lab work. Creativity and academic achievements are two related areas which will be studied.

(4) Describe any relationship between process lab work and lab learning styles, and make recommendations to improve students' performance in process science lab work.

The development of the lab learning style types and lab process studies were performed with the researchers classroom students. The testing of the Lab Learning Style Inventory, was performed in many schools with many different populations.

My initial hypotheses that were tested in this thesis included:

Learning styles affect lab process science, and this effect can be measured.

By considering student learning styles during lab design, teachers can improve student performance in science labs.

A goal for this study is to develop a lab learning style instrument which would give science teachers a practical, inexpensive assessment of students' learning style.

DEFINITIONS

This study undertakes a large area of subject matter, and terms are important to help clarify the researcher's goals. The study takes a fairly specific area (science lab learning style) and applies this to the general area of exploratory lab science. Two areas of this study include the students' learning style and exploratory lab science. Each area will be discussed separately.

Learning styles can be defined many different ways for different purposes (Entwistle, 1981). The area of learning style research is one that has many different approaches, techniques, and instruments. One could easily become confused in the midst of different terms and names. An overview of the learning style literature is presented in Chapter 2. Of particular importance is Judith Reiff's Learning Style Profile described in Chapter 2. This profile reviews and synthesizes the major work in learning style research. The intent of this study is not to formulate a new learning style framework, but rather to take the existing learning style work and apply it to lab science students. For the purposes of this study, learning style is defined as: *Those factors, behaviors, and attitudes which facilitate learning for a science student in an exploratory lab environment.*

Science is the acquisition of knowledge attained through a process of testing hypotheses. Science is a "doing" activity as opposed to a listening activity. Unfortunately in many school classrooms, this is not the case. Students may attend science classes and never have the opportunity to design an experiment or formulate an hypothesis. Some science teachers may not recognize the "doing" nature of the word science. For this reason, words like "process" science, or "exploratory" science will be used to describe the procedure of students' performing science. Throughout this study, laboratory science is herein defined as that science and science methodology which the students perform. It does not include teacher demonstrations although these are recognized as valuable forms of instructions. This study approaches science labs from the standpoint of students "discovering" the process. This process means that a student is given a problem to solve and must use their powers of observation to discover what the correct solution will be. It is this 'discovering', that forms the basis of process lab science.

Process lab science is a catchall term that is used in different ways by different authors. In an article on process science, Lunetta and Tamir (1979) developed a comprehensive list of skills and behaviors related to student science lab performance. Their list is used here to generate four areas of process science.

The first area cited by Lunetta and Tamir is **planning and design**. How well does the student formulate a question or define the problem to be investigated? Can the student make a prediction from the experimental results? Is the student able to formulate a hypothesis? The experimental design the student chooses would be included in this area. The student's ability to identify variables and to control variables would be included in this section. From this design point, the student then prepares the necessary apparatus.

The second area is the **performance** area. This involves the student in carrying out both qualitative and quantitative observations or measurements. The student would need to manipulate the apparatus, perform numeric calculations, and record results.

The third area involves the **analysis and interpretation**. This section has the student arranging data in tables or diagrams. The student would analyze this data for relationships that may exist. The student determines the accuracy of the data and uses this data to formulate a generalization or model. The student may also formulate new questions based upon the results of the investigation.

The fourth and final section is the **application**. Can the student make predictions based upon the results of his investigation? Can the student apply the experimental technique to a new problem or variable? The student may also suggest ideas and ways to continue his investigation.

These four areas provide a fairly comprehensive description of lab process skills. Learning styles could affect a student's performance on any one or part of the above skills. This study needs to survey the entire area of exploratory lab process science.

For the purposes of this study, process lab science shall include, but not be limited to *a process that has students (1) observing and measuring; (2) manipulating the equipment; (3) planning and designing of experiments; and (4) interpreting data to formulate generalizations.*

LIMITATIONS OF THE STUDY

This study relates learning styles to process lab science. This results in some limitations for this study. Some limitations are described below:

(1) Although the study hopes to show a relationship between learning styles and process science, it does not identify specific student strengths or

weaknesses in science process skills such as observing or manipulating equipment. A student may be good at collecting data and graphing this data, but may not be good at interpreting the results which the data show. This study will not test or recognize areas such as these.

(2) Due to the complex nature of process science labs, there are many factors other than learning styles potentially influencing the students' performance in these labs and these factors will not be investigated here.

(3) There are many facets to the area of learning styles. This study attempts to isolate key aspects of learning style that relate to lab science learning. In order to make the study manageable, an attempt is made to use the existing learning style data to classify and help science lab learning style students. There are many parts of the learning style paradigm which this study omits. An example of this omission is that some areas of the physiological part of the learning style paradigm are not studied. Students were not asked their preferences or given choices of time of day, temperature or light conditions or other physiological factors that could affect exploratory lab performance.

(4) The population studied is also a limiting factor. Although the lab learning style instrument developed in this study was initially tested on over 500 students in grades sixth through ninth from a variety of communities, other portions of the study, including assessment of student abilities in process science labs, and studies in creativity and standardized test achievement were done only with seventh and eighth grade students at a single rural school. Thus some of the generalizations arrived at may not extend to other levels or school settings.

(5) The time which this study encompasses may be seen as a limitation. The data-gathering for this study was carried out by one researcher during a

three year period. A study of this nature could easily encompass many years, and involve more than one researcher.

SIGNIFICANCE OF STUDY

This study has many important factors to it.

Throughout the study, students were constantly made aware of various learning styles especially, their own personal style. Students were made aware that there is not any one right style, but rather there are many different styles. Everyone has different strengths and weaknesses. The important factor is to work on one's weaknesses and accomplish important tasks with one's strengths. It goes back thousands of years to Socrates who stated: "Know thyself." Anyone or any study that uses learning styles helps accomplish this.

Teachers involved with learning style work realize the importance of teaching too many different styles. Classes are full of students with different styles, and it is important to address as many styles as possible. When teaching, it is important to present work in all modalities whenever possible. One should strive to provide written instructions, verbal explanations and visual demonstrations for all teaching activities (Barbe & Swassing, 1988). This study helps sensitize teachers to these ideas. The study pursues the area of lab activity design. There are many factors that contribute to good lab activity design. This study adds more to the knowledge base of ways and techniques to design better labs.

The study looks at mixing and matching students with different lab learning styles. What is the effect of having two people work together with dissimilar styles? What is the effect of having two people work together with similar styles? When students are allowed to choose lab partners, what style do they choose and is there an increase in student performance based on this choice?

When performing exploratory lab science, one is re-creating a work place environment. People in labs, as in other work places, are gathered together to accomplish particular purposes. Information gathered from this study could be helpful to future employers hiring and supervising employees. The employer may want to “mix and match” learning styles during hiring or, more importantly, structure the work environment to enable individuals with different learning styles to perform successfully.

The study provides one more look at the way students learn and perform in the science lab. Despite the limitations, any ideas that are discovered as a result of the study should be beneficial to other teachers.

CHAPTER II

A REVIEW OF THE LITERATURE

LEARNING STYLES

Learning styles are not a new phenomenon. There are records that trace back to Aristotle's time indicating that each child has special talents (Osborn, 1975). Educators throughout time have recognized that individuals are unique thus must be taught in different ways (Klein, 1951). In the early 1900's personality studies were completed and learning styles started to become classified and labeled. Much of this early research in learning styles studied the relationship between memory and the type of instructional methods used (Lowenfeld, 1945). The study of learning styles developed and branched out in the 1900's. Educators attempted to use learning style models in their classrooms.

Throughout the latter part of the 1900's, instrumentation was being developed to "label" various learning styles. Researchers seemed to develop their own learning style frameworks and their own learning style instruments. Classification terms such as concrete random, kinesthetic/tactile, thinking judgment, extroverted, intuitive and many others, started appearing in the literature. The literature is full of learning style jargon. Even in 1992, understanding of various learning style profiles and their interconnections seems limited. An issue of Educational Leadership devoted to learning styles (Jan., 1979), took an article by article approach to this field. Each article presented a different learning style methodology and instrumentation. The reader was left with the idea that there are many different ways to categorize learning styles, and one should pick the favorite article and use that framework.

More recently an issue of Educational Leadership (Oct., 1990), entitled "Learning Styles and the Brain", presented research on learning styles as they are affected by personality and cognitive development. This issue contained articles on left brain/right brain research, brain processing techniques and multiple intelligences.

Reiff (1992) published a recent synthesis of research on learning styles (See Learning Style Profile chart). Her Learning Style Profile includes three major domains, Cognitive, Affective and Physiological. The Cognitive is based upon brain development and information-processing research. The Affective domain includes the personality and emotional factors. The Physiological domain includes factors in the student's physical environment. Each of these three domains is further broken down into sub-categories that are briefly discussed below.

COGNITIVE DOMAIN:

This domain is broken down into six sub categories.

Brain Dominance -This area deals with the left brain/right brain hemispheric dominance theories (Levy, 1983). Characteristics of the left hemisphere include verbal, sequential and analytical abilities. Dominant traits of the right hemisphere are global, holistic, and visual-spatial. Both hemispheres are equally important in our lives.

Conceptual Tempo - This area deals with the individual's consistent tendency to approach problem situations either rapidly or cautiously with accuracy or inaccuracy (Kagan, 1965). Impulsive students are quick-to-respond, risk takers who easily become bored. Reflective learners prefer to concentrate, analyze and do not like to be wrong. Both types of learners are present in schools and classroom science labs.

Mindstyles - This theory maintains that individuals think either abstractly or concretely and that their thoughts are either sequential or random (Gregorc, 1979). Students who benefit from an ordered, step-by-step approach to a science lab may have difficulty with an unstructured, holistic, creative approach to science labs.

Modalities - Modalities are pathways or channels through which people receive and learn information. The three basic modalities include: Visual, Auditory and Kinesthetic (Barbe & Swassing, 1979). Students that rely primarily on listening and hearing instructions, may experience frustration when confronted with written instructions.

Field Dependence/Independence - This category deals with how people memorize and learn information. A field dependent person is distracted by a complex background and a Field Independent person is not distracted. Field independent people may favor a math or science area, and a field dependent person may favor the humanities (Witkin, 1973). A field dependent student might enjoy the cooperative learning aspect of science labs, but may need the teacher to model how to organize the lab information.

Multiple Intelligences - This area was pioneered by Howard Gardner. He feels there is not one intelligence measured by a test, but rather at least seven intelligences. He felt that some people are stronger in some areas of intelligence than in others. His intelligences included, Bodily-Kinesthetic, Linguistic, Logical Mathematical, Musical, Spatial, Interpersonal and Intrapersonal (Gardner, 1983).

LEARNING STYLE PROFILE

Cognitive

Brain Dominance
* Analytical
* Global
* Integrated

Conceptual Tempo
*Impulsive
*Reflective

Mindstyles
* Concrete sequential
* Abstract random
* Abstract sequential
* Concrete random

Modality

* Visual
* Auditory
* Tactile
* Kinesthetic
* Integrated

Multiple Intelligences

* Bodily Kinesthetic
* Linguistic
* Musical
* Spatial
* Intrapersonal
* Interpersonal

Psychological
Differentiation
*Field dependence
*Field independence

Affective

Conceptual Level
* High
* Low

Psychological Types
* Thinker
* Sensor
* Feeler
* Intuitor

Physiological

Elements
* Environmental
  sound, light, temp., design
* *Emotional*
  motivation, persistence
  responsibility, structure
* Sociological
  self, pair, peers, team, adult
  varied
* Physical
  perceptual, intake, time, mobility

***1991, Judith Reiff, Un. of Geo., Athens, Ga.

AFFECTIVE:

Conceptual Systems - This concerns how individuals impose structure on their environment. Conceptual systems range from those of people who view things from a narrow perspective to those of complex individuals who are flexible, independent, and tolerant (Hunt, 1988). Students at a high conceptual level are more independent, needing less structure.

Psychological Types - This area was based upon the work of Carl Jung. He identified four different psychological types, Sensors, Intuitors, Thinkers and Feelers.. Each of these types were based upon how individuals viewed their environment, and interacted with their world (Jung, 1921). The Sensors are realistic, present-oriented people who like to memorize facts. They are patient with details and prefer a sequential approach to problems. The Intuitors are imaginative, inventor type people who like problem solving. They are often Global and impatient with routines. The Thinkers are logical, objective people. These analytical people are concerned with principles of justice and fairness. The Feelers are subjective people influenced by emotions. They value harmony.

Combine attitudes of Extroversion and Introversion with orientations to the world of either Judgment or Perception, and one has all sixteen types used in the Myers-Briggs Inventory (Myers & McCaulley,1990). This is the most popular instrument used to measure psychological types, and is probably the most commonly used Learning Style Inventory in existence. Many employers use the Myers-Briggs to "inventory" their employees. A person classified as INFJ (Introverted Intuition with Feeling) might be someone that is independent and individualistic and governed by inspirations that come through intuition. Because of the relatively high reading level of the Myers-Briggs Inventory, it is not a commonly used instrument in schools.

PHYSIOLOGICAL:

This domain looks at students' preference towards their physical environment. The physical environment is divided into four major areas. The areas are environmental, emotional, sociological and physical. The environm ental area is concerned with sound, light, and temperature. The emotional area considers motivation, persistence, responsibility and structure. A person's preferred method of learning would be included in the sociological area (peer, self, team or adult). The physical stimuli include what time of day the student prefers to learn, and whether the student prefers mobility during learning.

This area was popularized by Ken and Rita Dunn. Their self-reporting inventory looked at learners' preferences towards the above four areas Their inventory developed in 1975 has been tested on thousands of people and used in hundreds of research projects (Dunn & Dunn, 1978). A complete discussion of the Dunn and Dunn Learning Style Instrument (LSI) is found in chapter three. The reading level of the LSI makes it suitable for middle school students.

RESEARCH REVIEW

The learning style framework used in this thesis primarily relies on the work of Carl Jung, using instrumentation adapted from the Myers-Briggs survey and the work of Barbe and Swassing (1979). An instrument developed by Dunn and Dunn was also used in this study for data gathering. This research review looks at earlier studies that made use of the instruments developed by these three research teams. Research that studies learning styles in relationship to science labs will be discussed in the last section of this chapter.

Research based upon the Myers - Briggs Instrument.

Due to the reading level of the Myers-Briggs instrument, it is mainly used with adults. One school study used the Myers-Briggs Indicator to identify student learning styles. Students then preferred a curriculum program. It was found that Intuitive students selected curriculum that had new possibilities such as being able to select their own courses, and avoided a curriculum perceived as static. Sensing students sought experiential approaches to learning (Steele, 1986). This study supports findings that students seem to select the curriculums that fit their learning styles.

Research based upon the Dunn and Dunn Instrument.

The Dunn and Dunn Learning Style Inventory was developed and tested for use with fifth through twelfth graders. Because of its' reading level and the research support given by the Center for Learning Style Research located at St. Johns University, N.Y., The Learning Style Inventory (LSI) seems to be the most commonly used learning style instrument in school classroom research.

Research using the LSI seems to indicate that there is a relationship between learning styles and academic achievement. This research seems to be consistent in demonstrating: (1) Students do learn differently. (2) When students are taught using approaches that utilize their individual learning styles, their academic work improves. The above statements are supported by research from: DeBello, 1985; Dunn, DellsValle, Dunn, Geisert, Sinatra, and Zenhausern, 1982; Giannitti, 1988; Hill, 1987; White, 1980; Hodges, 1985; Jarsonbeck, 1984; Kroon, 1985; Lemmon, 1985; Lynch, 1981;, MacMurren, 1985; Martini, 1986;

Miles, 1987; Murrain, 1983; Pizzo, 1981; Shea, 1983; Spires, 1983.

Cited below is research which supports the hypothesis that students perform better in classes where learning style is taken into account by the teacher. The implication of these studies is that students may perform better in science labs where learning style preferences are considered.

Spires (1983) studied the results of using learning style preference to teach reading and math to K-6 graders. He found significant gains were made when individual students learning styles were addressed.

Price (1980) administered the LSI to 3,972 subjects. These students were in grades 3-12 during the 1979-80 school year. He analyzed the results from the twenty-two item LSI and found:

(1) The higher the grade level, the more a student preferred sound and light.

(2) The higher the grade level, the less preference a student had for a formal design.

(3) Self motivation decreased during the 7 & 8th grade year, but then increased slightly in the grades after.

(4) The higher the grade level, the less teacher-motivated a student was.

(5) There was less of a need for structure in higher grades.

(6) The younger the student, the more tactile and kinesthetic they seemed to be.

Lynch (1981) looked at time of day learning style preference and school attendance. He found that the matching of individuals' schedules on the basis of learning style preferences affected attendance more significantly than matching students with preferred types of teachers. He also found that a correlation did exist between academic achievement and the number of days of partial or full truancy. It seemed that the single influence on the reduction of truancy was to match the students' learning style preferences with their course period schedule. Students that had courses corresponding to their preferred time of day learning style, wanted to attend school.

Miles (1987) used the LSI to study social preferences, achievement, attitudes, career awareness, and career decision-making. Out of one hundred and twenty-eight fifth and sixth graders in an inner-city, elementary school in New York City he targeted forty students who indicated preferences for either learning alone (n=22) or learning with peers (n=18). Students' attitude scores and academic scores were higher when they were taught in patterns that accommodated their preferences.

Griggs, Price, Kopal and Swaine (1984) tested 165 sixth grade, suburban students. Students who indicated high or low preference for structure and motivation were targeted. These students were divided into two groups. One group was taught with their learning style preference and the other group was instructed in traditional ways. Students whose learning style preferences for motivation and structure were matched scored significantly higher than the other group.

Hodges (1985) performed research concerning math test scores, learning style, and attitudes. She identified the design preferences of 7th and 8th grade remedial math students. Students were targeted as either formal design (e.g.- sitting in desks studying) or informal (e.g. - sitting on a rug studying). The group that was instructed using a design they preferred demonstrated statistically higher mean test scores, and a more positive attitude. Her findings suggest that

(a) junior high school math underachievers may not be matched with complementary instructional environments; (b) a testing situation can impact a student's academic performance and attitude; (c) low math achievers learn differently and therefore must be taught differently and (d) educators need to reevaluate how remedial programs should be structured.

Virostkos (1983) investigated the relationship among class instructional schedules, learning style time preferences, and grade level, and their effect on math and reading achievement. His study involved 286 third, fourth, fifth, and sixth graders. Groups were formed that either matched their time preference or mismatched their time preference. He found that students whose time preferences were congruent with instruction performed better academically.

Pizzo (1981) studied students' reading ability and the students' preference to noise. Some students indicated a preference toward studying in quiet, and other students preferred noise while studying. Groups were divided and tracked as far as gender, noise level preference and reading comprehension. He found that there was a difference as far as learning preference and reading comprehension. Students who preferred a quiet study area performed better in quiet settings, and students who preferred a noisy environment performed better in noisy settings. He did not find any differences in acoustic environment preference by gender.

Krimsky (1982) used the LSI to study the relationship between reading comprehension and students' preference toward light. Two groups, one that preferred bright light, and one that preferred low light, were used. They were randomly split into two test groups. The treatment for one test group was a dimly lit environment, while the other group had a brightly lit environment.

Students who were in their preferred light environment scored higher in reading speed and accuracy.

Shea (1983) performed research involving reading comprehension and design. Students that preferred formal and informal design were randomly split and divided into two groups. One group was taught while sitting on wooden or steel chairs (formal design), and the other group was taught while sitting on pillows (informal design). The group that was taught with their learning preference scored significantly higher in reading comprehension.

Martini (1986) investigated how students' preferences for auditory, visual, or tactile learning affected science achievement and attitudes of seventh graders. The LSI was used as the learning style instrument, and the Wepman Auditory Discrimination Test (WADT) was used as the auditory test instrument. The science unit taught was on the human body and made use of cassette tapes, and computer-assisted instruction. The auditory students, who used the cassette tapes scored higher than the visual and tactile students in the same group. Interestingly, students perceived strengths as tested by the LSI agreed with their actual strengths as measured by the WADT. The study did not mention any effect on the computer assisted instruction.

Kroon (1985) experimented with teaching industrial arts students through their learning style preference. He taught two auditory, two visual and two tactile lessons. Students that were taught using a method that matched their learning style scored higher than students who were not.

DeBello (1985) used the LSI to study 236 eighth grade students in a suburban school. His research measured students' preferences for peer, self, or adult learning. He found that attitudes were significantly improved when students were taught in ways that matched their learning styles. His study also revealed that achievement scores were significantly higher when instructional strategies were matched to learning style.

Kroon (1985) administered the LSI to 65 industrial arts students. His study focused on the students' modality preferences (auditory, visual or tactile). He found significant increases in achievement when students were instructed in their primary learning style and then reinforced with their secondary style.

Murrain (1983) studied 268 seventh graders. He used the LSI to diagnose preference for their classroom temperature. He randomly divided the two groups, matched one group for their preferred classroom temperature, and left the other group as a control. He found higher scores when instruction was congruent with their preferred temperature environments.

Another environmental study was Shea (1983). He used 410 ninth graders to determine student preference for environmental design. His study took two extreme IQ score groups and randomly assigned them for reading comprehension in formal or informal design settings. Results showed significant comprehension score increases when students were matched to their preferred leaning style.

The studies mentioned above used the Dunn and Dunn instrumentation that was used in this study. Techniques such as matching students with their preferred style, were used in this study. These studies indicate significant gains in achievement and attitudes when students are able to learn in ways consistent with their learning styles. Though the majority of the research supports learning style congruency with instructional methods, there are also studies that do not show any significant gains by teaching in accordance with learning style preferences (Conwell, Helgeson, Wachowiak, 1987).

PROCESS EXPLORATORY LAB SCIENCE

A second area of this study is exploratory lab science. This is another area in science that is not new. Socrates advocated "Socratic questioning", with an emphasis on the question, "Why did this happen?" This question represents process science at its best. The time period of Francis Bacon, Isaac Newton and later Descartes represented a time when society was asking the question, Why? Another of history's top exploratory proponents was Rousseau. In his Emile (Boyd, 1956) Rousseau wrote that the "child needed to explore and discover the meanings and lessons of life." He wrote that learning should happen by trial and error, and the more a child is exposed to various phenomena, the more understandable it would become. Exploration was the key to this approach to education. John Dewey brought exploratory education to American education in the late 1800's - early 1900's. His writings are full of references to the household kitchen being a science laboratory (Dewey, 1959).

Many educators were interested in the inquiry process. Joseph Schwab from the University of Chicago began writing monographs on the need for inquiry based science (Schwab, 1939). He continued research in this area throughout the 1940's and 1950's. He was one of many educators whose writings and influence led to the development of The Biological Sciences Curriculum Study (BSCS). The initial goal of BSCS was to develop and produce inquiry based materials for a first course in biology (Mayer, 1963). The project developed many variations based upon the experiences of over 1000 teachers and 150,000 students (Moore, 1968).

Jean Piaget in the 1940's identified four levels of thinking, and went on to state that whenever we learn something new, we need to go through these stages. One of his stages is Concrete Operational which would be the "hands on exploratory" stage of learning. Piaget would suggest that a person learning chemistry for the first time may have to go through the concrete operational stage via an exploratory experience (Piaget, 1973).

Building on Piaget's ideas, Robert Karplus developed an approach to science called the learning cycle. Karplus's learning cycle consisted of three stages (Karplus, 1967). Karplus indicated that learning would be optimized if students were taught using this approach: Exploration — Term Introduction — Concept Application. During the exploration stage the students collect data that are usually explained and clarified by the teacher during the term introduction stage. The concepts can be applied to further activities during the concept application. The University of Iowa in 1984 undertook Project PRISMS. This was an inclusive program to teach physics to high school students. Each physics module had two "hands on" lab activities. The first of these laboratories was an exploratory activity (Unruh, 1985). The teacher would clarify the data and explain any vocabulary during a term introduction, followed by another lab application.

The exploration phase contains many steps (Lawson, 1988).

(1) The students learn through their own actions and reactions to the experiment. They test and retest the situation usually with little guidance from the teacher.

(2) The students may experience new questions from the exploratory activity, and the activity may challenge their preexisting ideas. Their usual pattern of reasoning may not fit into the exploratory activity and they may need to attempt another line of thinking.

(3) Exploration also leads to identification of patterns. The students may be faced with finding patterns that their experiment fits into. As an example, a student faced with an exploratory activity on heat, may be asked to predict the resulting temperature when two cups of equal amounts of water are mixed together. The student must make a hypothesis, then perform an experiment to test the hypothesis. The student then must collect the data and use the data to reason out the answer.

Lawson's discussion of exploratory lab science identifies a number of observable components. The student is involved with **performing** the lab. This skill involves setting up the equipment and carrying out the lab. During the investigating skill, the student collects data and makes observations. The student is also involved with using **reasoning** skills throughout the lab. The questions of what happens during the experiment and why it happens demand use of this skill. These three skills become the focus of this study's application of learning styles with exploratory lab science.

Is the exploratory phase a required phase of learning? A study performed by Renner, Abraham and Birnie (1988) indicates that it is necessary to perform each part of the learning cycle. Their study involved 62 twelfth grade physics students. Students were divided into two groups, one being taught using all three parts of the learning cycle, and the other group having parts of the cycle omitted. Both qualitative and quantitative techniques were used to gather achievement and attitude data. Students who were taught using all three components of the learning cycle performed significantly better on all five post-test measures.

Another study looked at the sequence with which the learning cycle elements were taught (Abraham & Renner, 1985). Does the cycle need to be taught in the order, Exploration - Term Introduction - Concept Application? Six classes of high school chemistry were studied. All students were given achievement tests to create groups that were equivalent. Some of the groups were taught with the traditional sequencing of learning cycle phases, and some of the groups were taught with the sequence in a different order. In some cases, the group that was taught with the correct sequence order, out performed all other groups, but in other cases, other sequence orders brought better results. Their research brings out several important points. Exploratory process science assessment is an extensive area and inconclusive results are often possible. A second point was that an important phase of the learning cycle was the exploration phase. If the concept being taught is new to the students, performance seems enhanced if exploration comes before term introduction. The sequence in which exploratory activities occurs becomes important in this thesis, as some of the exploratory activities are performed after the concept is introduced and some are performed before the concept is introduced. Students appear to prefer sequences where the exploration phase comes later in the sequence. The students did not feel as comfortable dealing with exploration early (Abraham and Renner). The early exploration sequence may have been uncomfortable for the students, but provided a better learning sequence. The study did not deal with the possibility that this preference helped their learning.

This and other research helps establish the effects that exploratory science has on learning, attitudes, and success in science. Research or findings that help students and instructors work with exploratory labs successfully can help us design more effective science education programs.

LEARNING STYLES AND EXPLORATORY SCIENCE

No studies were found that specifically studied learning styles and exploratory science. There are several studies which look at learning styles and science, and these studies become important.

One study looked at the effect of mismatching or matching students' cognitive styles (psychological types) and science instruction. The subjects consisted of 56 inservice elementary teachers. They were classified using the Myers-Briggs Instrument and then divided into two treatment groups. The students' science knowledge was tested using a researcher designed instrument, and attitudes were measured using the Attitudes Toward Science and Science Teaching (Mayer, 1974).

The study did not find any effect on students' scientific knowledge or attitudes toward science resulting from the degree of match between science activities presented to the cognitive styles of the teachers. The researchers mention a number of limiting factors which may have produced the above results. One significant limiting factor was an instrumentation problem. The researchers felt that self-report, paper-and-pencil instruments such as the Myers-Briggs Instrument, may not reliably differentiate subjects, particularly near the mid range of preference scores. This problem may be one encountered in any learning style survey research (Conwell, Helgeson, and Wachowiak, 1987).

An earlier study looked at a similar effect only this time with high school chemistry students (Anamuah-Mensah, Erickson and Gaskel, 1981). This study looked at student attitudes, achievement and learning styles as related to a unit in chemistry. Both a learning style measure (Myers-Briggs) and an attitude measure called the Attitudes Toward Science and Science Teaching (ATSST) were used in the study. Achievement was measured by a researcher constructed test. The study did not find any effect on students' science knowledge or their attitudes toward science. Once again, the results may have experienced the same problems as the Convell, Helgeson and Wachowiak study.

An unpublished study encountered in the author's research was conducted at a middle school in Maryland. A guidance counselor and science teacher conducted a learning style-science project. Students were given the Dunn & Dunn Learning Style Survey. The results of the survey were shared with the students so that the students could identify their preferences, strengths and weaknesses. The students were then introduced to various science learning modules. The students were offered several choices of modules teaching the same science concept. Each module was taught a different way. The students selected a module based upon their identified learning styles. Statistical data were not gathered, however, the project staff felt that students' attitudes and academic work improved through this approach. Students naturally selected modules in their learning styles. It is interesting that students tend to want to learn in their preferred learning style.

Learning style research and exploratory science research are complex and often not conclusive. One is dealing with many variables, and control of all of the variables is often difficult or impossible. However, such research should not be thought of as wasted. A lot of valuable information may be discovered even when research involving a complex phenomenon provides no final answers.

This chapter attempts to synthesize two broad areas of research, learning styles and exploratory process science. The learning styles paradigm is one with a long history, and many different strands. The strands in this paradigm came one step closer to complete organization with the publishing of Reiffs' Learning Style Profile. This profile and instrumentation in the profile became the source in developing the studies Lab Learning Style Instrument. The second area of the study is exploratory process science. This is an area with a longer history than learning styles, and one with even more strands. Exploratory science needs a research synthesis to organize all the strands, terms, and methodologies into one plan. Because this has not been done yet, the study chose one strand, the Lawson model (Lawson, 1988), and used instrumentation from that to test exploratory science. Research involving learning styles and exploratory science is limited, which adds to the importance of this study.

CHAPTER III

PROCEDURES

The study of science lab learning style and the evaluation of exploratory lab skills involve a particular type methodology. The methods and reasoning behind the methods becomes the focus of this chapter.

The first area is that of lab learning styles. Current learning style instruments measure many areas, but do not specifically measure science lab learning styles. What are some lab learning styles, and how might they be different from the traditional learning style models? This is a new area and one which required some research and development. The steps involved in developing science lab learning styles included testing ninety-seven science students' learning styles, using instrumentation from three previously developed learning style instruments described in Table 1. Results were tabulated from each of these instruments and recorded for each student. This information, combined with sixteen years of experience in classroom lab oriented science, led to the development of four types of lab science learning styles. After the style types were identified, it would be necessary to develop an instrument to inventory the styles for each student. It is important to discuss the three instruments used in this process because they served as the criteria to determine the four types of lab learners, and subsequent Lab Learning Style Inventory.

TABLE 1

LEARNING STYLE INSTRUMENT TABLE

NAME OF INSTRUMENT	PURPOSE OF INSTRUMENT
MODIFIED SWASSING-BARBE MODALITY INDEX	This instrument assesses students' learning modality . (visual, auditory or kinesthetic).
MODIFIED MYERS-BRIGGS "The Thinking and Learning Style Survey for Adolescents"	This instrument assesses student personality characteristics then groups them into four basic types. Thinkers, Feelers, Sensors and Intuitors.
DUNN & DUNN LEARNING STYLE INVENTORY	This instrument assesses the Physiological domain. (ie. what type of environment, and with whom do students prefer to learn?).

The **SWASSING-BARBE MODALITY INDEX** is used to assess student modality. Modalities are ways that people receive, transmit and store information. Some modalities include visual (seeing), auditory (hearing), kinesthetic (movement), and tactile (touching). A student who learns primarily visually would be one that needs to see or read the information. Like most learning style instruments, modality tests are comprised of a series of questions to which students respond with their choice of answers. A student may be asked:

If I were putting a puzzle together, I would like the instructions........

To be written out so that I may read it (visual learner)

To be explained to me so that I may hear it (auditory learner)

To be in some form that allows me to try to put the puzzle together as I go along. (kinesthetic/tactile)

The student would answer a series of these questions, and total the scores in each area to find a modality preference. A student who choses a majority of visual choices would be labeled as a visual learner. Students whose score is low in a particular modality, may have a style avoidance in that area. The test used in this study to measure modality of the students is a modified version of the Swassing-Barbe Modality Index (See appendix A). The original Index had a reading difficulty greater than the ability of middle school students so the questions were simplified. The simplified version consists of thirty-two questions with three choices for each question. This simplified version along with the modified Myers-Briggs version used were developed by other researchers' and each applied to this study. Each choice corresponds to a modality strength or weakness. The modified Index was administered to ninety seven students and a modality score was obtained for each student. Although the Swassing-Barbe and Myers-Briggs inventories do not have validity or reliability scoring, combine the data obtained with information from the Dunn and Dunn instrument and it becomes possible to triangulate the results. Students who prefer a kinesthetic approach in the Swassing-Barbe instrument and the Dunn & Dunn instrument and also are categorized as Sensors in the Myers-Briggs instrument probably have a learning style approach towards manipulative learning.

MYERS-BRIGGS - The Myers-Briggs inventory is based upon the work of Carl Jung. The original inventory is suited for high school students and adults, but not middle school students. An adapted middle school version is used in this study. The version used is titled The Thinking and Learning Style Survey For Adolescents (See appendix B). This version has been used with thousands of students in an Alaska school district (Johnson, 1984).

Students are asked questions and given a selection of answers. They are to rate their answers on a one to four basis with a one being the answer they like the best, and a four being the answer they like the least. Totals are calculated in each of the Myers-Briggs categories and the standard deviations are computed. The students' learning preference is based upon their score range in respect to the standard deviation of the group. The preference score range for the Johnson survey is:

Category	Survey score range
Strong style preference	Above + 1 standard deviation
Moderate style preference	Between mean and +1 S.D.
Moderate style avoidance	Between mean and - 1 S.D.
Strong style avoidance	Between -1 S.D. and -2 S.D.

The format and scoring system used in this instrument is similar to the lab learning style instrument developed for this study.

DUNN AND DUNN LEARNING STYLE INVENTORY - The Dunn, Dunn & Price Learning Style Inventory (LSI) was the first comprehensive learning style survey developed. Developed in 1975 the LSI was most recently revised in 1989. The survey assumes that many factors affect student learning, but certain factors carry more weight for individual students.

The survey lists twenty-two learning style preferences in four general areas. The areas are (1) Environment (Sound, Temperature, Light, and Design); (2) Emotionality (Motivation, Responsibility, Persistence, and the need for either Structure or Flexibility); (3) Sociological needs (Learning alone, with Peers, with Adults and/or Several Ways; and (4) Physical needs (Time of Day, Intake, and Mobility). The results of these twenty-two learning style preferences are obtained by having the students complete a 104 item questionnaire. Questions like:

I like to have an adult nearby when I do my school work.

are answered in a Likert scale. The results are computer tabulated, and an individual profile is drawn up for each student.

The standard scoring for the LSI ranges from 0 - 80 with a mean of 50 and a standard deviation of 10. For this reason, the significant scores will lie somewhere between 0 to 40 or 60 to 80. Scores falling between 40 and 60 would be in the average, and would not indicate any marked preference. The LSI inventory also has a consistency score. Some of the 104 questions are parallel versions of other questions , so it is possible to see if students are reading each question and giving consistent answers. A consistency rating of at least 70 percent, indicates that responses to 70 percent of the item pairs were in agreement. Students with 70 percent consistency ratings would have an accurate profile. This type of consistency rating was used in developing the Lab Learning Style Instrument for this study.

Of the three instruments described, the LSI has been statistically tested the most and is the learning style instrument most often cited in middle school studies. The reliability was checked in 1988 based upon 890 randomly selected subjects in grades 5-12. Virostko's research (1983) found a Pearson Product Moment Correlation of .929. Copenhaver's research (1979) determined that learning style preferences remain consistent over time. Because of the reading level, reliability and consistency ratings, the LSI contributed in important ways to the development of the Lab Learning Style Inventory. The LSI was a tested instrument used in many middle school studies, and data obtained from it can be interrupted as reliable and valid. Of the LSI's twenty-two areas, eleven were identified as having a potential effect on lab learners. These eleven areas that helped establish the Lab Learning Style Inventory include:

DESIGN - This implies whether the student prefers a formal design or a more informal design in instruction. In science, formal design preference might mean that a student prefers to learn while sitting at a desk, while an informal design might mean that a student prefers to learn while sitting on a carpet or standing beside a lab table. It is also plausible that strong exploratory lab learners will prefer a more informal design.

MOTIVATION, PERSISTENCE, RESPONSIBILITY -These areas inventory how students perceive themselves. Do the students feel they are motivated by themselves, by peers or by parents? Do the students feel they are responsible or persistent in their school work? Do high academic achievers perceive themselves as responsible and motivated? Is there any relationship between motivation, persistence and responsibility? These are questions that may apply to science instruction and were studied when using the LSI to develop the various types of lab learners.

STRUCTURE - Do strong exploratory lab learners prefer less structure? Is there any relationship between students that prefer structure, and students that prefer formal design? Structured students may prefer assignments where everything is explained and very little is left open to interpretation. This may be relevant to exploratory lab work because of the open design of such labs. In many labs the student is testing hypothesis to find out information.

PEERS & AUTHORITY FIGURES -This area pertains to whether students prefer to learn alone or with groups. Are there any relationships between students' social preferences and the ability to perform lab process science? This area also considers how students prefer authority figures to interact with their learning. For example, in one science class a teachers' style might be one of working in small groups with most learning happening through this small group experience. Another teaching style might be one that creates an atmosphere of individual learning through a textbook. Because of the social arrangement used in science classes, this area was one selected as being important.

AUDITORY, VISUAL, TACTILE & KINESTHETIC -The Dunn and Dunn instrument, like the Swassing-Barbe instrument, considers modalities. Is there any correlation between modalities and students' lab learning types? Some modality items from each inventory were used in the present study. The following reliabilities have been established for the four modalities examined in the LSI:

Visual - .79 with standard error of 2.18

Auditory - .80 with standard error of 2.22

Tactile- .77 with standard error of 1.51

Kinesthetic - .74 with standard error of 2.4

This data was obtained from 890 students in grades 5-12 , and was tested with Hoyt's Reliability (Dunn, Dunn & Price, 1987).

DEVELOPMENT OF SCIENCE LEARNING STYLE TYPES

Students were administered the three learning style inventories and results were compared. The results produced three distinct patterns which seemed to keep occurring throughout the study.

Some students seem to produce very reliable results. If such a student was an auditory learner in the Swassing - Barbe Inventory, he or she typically was an auditory learner in the Dunn and Dunn survey. Even when the same survey was given a year later, the students still achieved very consistent results.

Some students demonstrated strong learning preferences on one instrument, and showed weak learning preferences in the same area on another instrument. When these students were re-tested one year after the original test, their learning style preferences had sometimes shifted dramatically.

Some students did not show any particularly strong learning preferences, but were balanced in all areas.

TYPES OF SCIENCE LAB LEARNERS

The group of students that produced strong consistent results became the target group. These students and the results of their inventories served as the basis for identifying learning styles patterns for science lab students. These students were identified as the strong lab learning style group in this study. Three distinct styles were apparent in this group. These styles were labeled as Type I, Type II, and Type III. Type I students preferred organization and good grades. They preferred to get answers on labs right and liked a structured learning situation. Type II learners perceived themselves as being unorganized, preferred the lab setting because they could manipulate the equipment, and learn in an informal design. Type III learners preferred the social setting of the lab. They enjoyed labs because they could work with a partner in a social setting. They preferred to learn with their peer group as opposed to learning from a teacher. There was a group of students that did not fit in any of the previous categories so a Type IV learning style was created. These students seemed balanced in all three learning style types or else they did not have a long term definite style.

Throughout the study, students and teachers would be introduced to these four types of science lab learning styles so a description of each type was needed. A teacher version was developed to make instructors aware of the types of lab learning in their classes. A copy of this teacher version is found below.

LEARNING STYLES IN EXPLORATORY LAB STUDENTS

(TEACHERS COPY)

These lab learning types come from (1) the Dunn and Dunn Learning Styles Instrument, (2) the Swassing-Barbe Modality Instrument, (3) the modified Myers - Briggs personality instrument, and (4) teacher observations, tests, and student interviews.

TYPE I

These students seem to be in the cognitive domain of Reiff's learning style profile. They perform well academically, "giving the teacher back what the teacher wants". They prefer to have all the work laid out for them. They seem to work in many modalities, but favor the visual or auditory. Generally they have Mindstyles of Concrete Sequential (Gregorc framework), and have a Thinker Psychological type (Myers-Briggs framework). They prefer structure and design in their classes and generally perceive themselves as being responsible, motivated and persistent.

TYPE II

Students seem to prefer doing the lab. They like to be in science labs, set up the equipment and "play". They seem to learn best by trial and error. If the teacher is explaining directions, they may not be listening. If there is a written lab, they may not read it. Give them the equipment, and let them go to work. They go from one experiment to another with what appears to be little direction. They may not write things down, and if they do, it may be very sloppy. They may not have the organizational skills to turn in their labs, and frequently they do not bring a pencil or paper. However, give them the equipment, and they can create all types of things. Their Mindstyle might be of any type in the Gregorc system, but usually not Concrete Sequential. Their modality is almost always Tactile or Kinesthetic. They seem to be Impulsive Type learners and their psychological type is usually Sensor or Intuitor(Myers-Briggs framework). They prefer an unstructured design, like mobility, like to eat while doing other things and generally perceive themselves as not being very responsible or persistent.

TYPE III

This type of student enjoys labs for their social implications. They like to be around people, and labs allow this possibility. Many are interested in the science outcome of the lab, but first and foremost they like the social interaction. They seem to fall into most any Mindstyle and Modality. This type of person would have Interpersonal Intelligence (Gardner framework). If they are positive toward school, then their attitudes and performance in the lab will be strong. On the Myers - Briggs test, they almost always display a Feeler Psychological type. In many cases they prefer to stay with the same lab partner, and that lab partner is usually a Type III.

TYPE IV.

These students comprise the majority in science classes. They are a combination of all of the above types. They do not show a preference for any one style. They should identify with elements of all the types since they have characteristics of each.

After the LLSI is scored and returned to the students, a description of each of the types is given out. Students can read about some of the characteristics of their lab learning type and find some suggestions to help them in their lab work.

LEARNING STYLES IN EXPLORATORY LAB STUDENTS

(STUDENTS COPY)

There is not any 'right' style to be in the science lab. Each type has its advantages and disadvantages. In reading your type (s) you should remember:

These are GENERAL descriptions! They will not fit all of your characteristics. They will not be 100% correct. There will always be exceptions.

You should find out what characteristics of your style help you. Keep those parts! They make you unique, different and special. Work to make these characteristics stronger.

You should find out what parts of your style you need work on. Know your weakness (es), and set up concrete, measurable ways to improve them.

Find your major type strength. Read some general characteristics that may help you in a science lab. Find your major type avoidance. Read some general characteristics of things you may avoid in a science lab.

TYPE I

You are probably very organized. You may take good notes, preferring teachers that explain or write all directions down before you start. You like to know what the grading criteria will be before you start. You might prefer that information be presented in a logical sequential fashion, and you may become frustrated when it is not. The unstructured science lab may sometimes bother you, if this setting is part of a grade. You may become frustrated with the nature of exploratory science labs. In these labs you are being asked to explore a science area without many concrete, sequential directions.

TYPE II

You really enjoy the chance to do lab work. You may not care to sit and read, or listen, but you do like to 'fool around in the lab'. You enjoy setting up the equipment and trying out the lab material. You like to create your own lab, and sometimes have trouble working through the class lab. If something more interesting comes up while you are in the middle of working on the lab, you will probably try the more interesting route. You might have difficulty getting organized and getting work turned in. You may not like to write things down, you would rather do the activity. You will need to organize your work, and keep lists of requirements. You need to realize that 'great ideas' need to be documented, and followed through.

TYPE III

You are a people person. You like to be around people, and do things with people. You are probably very sensitive toward people, and you care about their feelings. One reason you like science labs is because you get to work with a lab partner. You have a lot of ideas to share with someone, and they have a lot of ideas to share with you. This exchange of ideas means that you work well with people. This is a valuable characteristic that may help you in your future occupation. You will have to be careful not to spend all your time working with the same person. Force yourself to work with different lab partners, and force yourself to stay on task. It will be tempting to put the person before the activity.

TYPE IV

You either do not have a dominant style or else the survey did not reveal any style. If you do not have a dominant style you should read each of the above descriptions to use some elements from each of them.

LAB LEARNING STYLE INSTRUMENT

Once the learning style characteristics were identified and labeled, it became necessary to develop an instrument to identify each type. The format of the modified Myers- Briggs instrument was chosen because it provided a quick, economical, self-scoring system for teachers. Questions and answers were constructed with answers which would reveal the students' lab learning style. The students are asked to read each question and rate the answer which expresses their preference. A number three by an answer means they prefer that answer the most. A number one means they prefer that answer the least. A score is tabulated and a lab learning style is labeled. Initially the instrument was tested and each question was analyzed as to the construct validity.

This validity check was made by comparing student answers on the new lab instrument with responses for items intended to assess the same traits from the original three learning style instruments. A student that was a kinesthetic learner on the Swassing-Barbe instrument and the Dunn and Dunn instrument should be a kinesthetic learner on the new Lab Learning Style Inventory. The consistency of each question was checked, by comparing parallel versions of certain questions within the same test. Based upon the student mean and standard deviation, a scoring system was developed. This scoring system was further checked and verified throughout the study. See Chapter IV for a detailed analysis of the scoring system used. The Lab Learning Style Instrument was now ready for use. See appendix C for a copy of the instrument. The instrument was administered to over five hundred students from six different schools, four different grade levels and eight different teachers. Results were analyzed according to gender, grade, population and teacher. The means and standard deviations remained fairly consistent for all populations, genders and different teachers. Once the Lab Learning Style Instrument was developed, students' lab learning style could be assessed and labeled. How would these students perform on exploratory lab skills? The next step was to assess students' exploratory process skills.

LAB PROCESS SKILLS

The instrument selected to test the exploratory process skills of science lab students was the Second International Science Study (Kanis, Doran & Jacobson, 1990). This instrument was designed to measure the current state of process lab skills in student populations throughout the world. The instrument had eighteen process tests designed for fifth graders, and eighteen process tests designed for ninth graders. Each process test focused on one separate content area such as physics, chemistry or biology. Each process test also focused on an observable skill such as observing, design of experiments, or interpretation of data. The Second International Science Study (SISS) proved to be a valuable instrument to use in this study for a number of reasons.

It contained a number of process tests, 18 at each grade level, within one instrument. This provided a source of many different process items. The present study required a number of different tests because it would be necessary to establish a science lab process performance level for each student taking the test. Students were paired with other students to find the pair combination that produced the strongest possible process lab performance. All of this testing required many different lab process tests, and the SISS provided a source for these. A limitation of this instrument was that all the process tests were not of equal difficulty. Students often scored higher on certain process tests because the tasks and subject material were easier.

The SISS instrument provided a framework for detailed assessment of different skills and behaviors related to science lab performance. Students could be evaluated in terms of their planning and experimental design capabilities, and their ability to carry out the lab and interpret data. This provided a relatively detailed glimpse of a student's science lab process skills. A student may be good at planning and designing an experiment, but less skilled at interpreting the data. The SISS would assess this.

The SISS provided a practical approach to assessing the process lab skills of large numbers of students. The station technique used in the SISS, combined with the use of simple materials meant that a classroom of students could be tested in one forty-five minute period.

The instrument had two different levels of tests. One test was for fifth graders, and the other test was for ninth graders. This meant that the relatively simple fifth grade lab process test could be given, and the more difficult ninth grade version could also be used. The study required that students be categorized based upon their lab process skills, and the two levels of testing in the SISS allowed for this.

SISS is a tested instrument used in over 23 countries. In the United

States alone, over a thousand students took the process test. This testing resulted in statistics on the average test scores for students. This data could then be compared to results from the current study.

To administer the SISS process test, the classroom was divided into a series of test stations. Each station had the necessary equipment to perform the process test being given that day. The directions to the test were short and at a reading level of third grade. The equipment was familiar to the students and simple to set up. The students performed the lab process test and answered several questions on the test sheet. The test questions were short and concise, and there were no more than six questions on any of the process tests. If two process tests were being given on one day, the students moved to another station for the second test. When the students finished the test it was turned in for scoring.

The scoring procedure for the SISS is very objective. Depending on the test, scoring ranged on a 0 to 6 number scale. Each item in the student test question sheet is scored based upon scoring samples in the scoring manual, and a point criteria is totaled for student answers. The total points are tabulated and a lab science process score is arrived at.

The SISS was administered to individual students so that an individual science process lab score could be identified. This procedure required several process tests of different difficulty levels to be administered so that a reliable score could be obtained for each student. Once a process lab score and learning style score were obtained for each student, students could be matched with other students to see the lab process results. Would there be any relationship between a particular lab learning style, and the lab learning style of the partner they chose?

How would this lab team perform on process labs compared to the matched team? This matching process was based upon the students' learning style scores. Students of one learning style were matched with students of a different learning style. A Type I learner might be matched with a Type III learner, and this lab team would complete an SISS process lab. Students were also allowed to choose their own lab partners in some lab process tests. The SISS was not the only lab process instrument used in this study.

TEACHER-DESIGNED LAB PROCESS ACTIVITIES

Teacher-designed chemistry and electricity lab practicums were administered to the students. These lab practicums did not in all instances test students' exploratory skills, but did test the: ability to manipulate science equipment, carry out laboratory procedures, and their understanding of the scientific concepts involved. Students who are more effective learners in process science may also reveal this in process science assessments like a lab practicum. The lab practicum had students solving a series of test problems such as determining which of three liquids had the highest acidity. Answering this question required the student to perform a simple titration with the liquids. Activities such as these lab practicums, evaluated the ability of students to set up and perform science labs and take previously learned lab information and apply it. Students were not instructed how to solve the problem, but only instructed as to the problem. The student had to design and perform the experiment, and make interpretations from the data as to the correct answer.

In addition to the lab practicums, a teacher designed exploratory science process activity was used. This activity presented students with the problem of finding which of five 'dinosaur nests' had 'sediment' materials common to them. The student was provided with all the required testing materials, but was not given any direction as to how the materials should be used to solve the problem. Once again, the student had to design and perform the experiment, and interpret the data to form his conclusion. The SSIS process labs and the teacher designed lab activities would give this researcher an indication how students performed on exploratory science activities. As the research on lab process skills progressed, it was realized that there were many potential factors involved in lab process skills. It became necessary to test some related areas.

CREATIVITY

An area which becomes very important in exploratory lab process is creativity. How creative is a student attempting to develop new and different approaches to a science problem? Is the student able to take traditional ideas and equipment and use them in creative, original ways? Is there any relationship between creativity, learning styles and the ability to perform lab process activities? Because of a possible relationship, creativity is an area which is included in the study. The instrument selected to test creativity was the Torrance Test of Creative Thinking (Torrance, 1990). The test is in three sections with each section requiring the student to make drawings. The first section has a drawing of an "egg". The student is supposed to complete the picture making the egg the main part of the picture. The picture is to tell some type of story and the student must come up with a title for his picture. The second part of the test provides the student with ten different curved lines.

The student attempts to make a picture which includes the curved lines as the main focus of the picture. The third part of the test provides two parallel lines. Once again, the students are to use the lines as the main focus of their picture. There are thirty sets of these lines, so the student attempts to draw thirty different pictures within the ten minute time limit. Each picture is scored based upon guidelines from a scoring manual, and a raw score is obtained. Although the test analyzes a number of components of creative thinking such as fluency, originality, and elaboration, the interest in the present study was in the overall creativity of each student. An overall creativity score for each student was obtained by using tables to convert each raw score to a standard score. The standard score provides a comparison between the student's creativity and the creativity of the large international sample to whom this test has already been administered. The standard mean of the Torrance test is 100 with a standard deviation of 20. Student scores that are below 80 indicate weaker creativity, and scores over 120 indicate stronger creativity. The Torrance test also allows comparison of the overall creativity of one student to a national sample of students in the same grade. A student in the 59th percentile scored higher than 58 percent of students in the same grade. Both of the mean creativity scores and percentile rankings provided valuable insight into the creativity of the students in the present study.

The Torrance Test has been used extensively for over 25 years in grades K - 12 in many countries. The Scholastic Testing Service which administers the Torrance Test, provides a "Norms-Technical Manual" which lists and details all statistical aspects of the test. Information of interest for the present study includes the reliability and validity of the Torrance test. The overall reliability coefficient for grade 8 is .98. The overall predictive validity of the test is .79 at a .01 confidence level. It should be noted that only 5 of the 98 coefficients of correlation failed to attain statistical significance at the .05 level of confidence or better. The Torrance Test is a reliable and valid test of creativity to use with this study, and it provides a tool to relate students' creativity to their science process abilities and lab learning styles. It would be interesting to develop a manipulative version of the Torrance Test. The student might be given a set of equipment and asked to design as many different ways as possible of using the equipment to test a given hypothesis.

PUZZLES

The puzzle test is a new test unique to this study. The puzzle test was developed because of the possibility that students able to solve puzzles may be good at exploratory lab activities. In solving a puzzle, a student must try to visualize the final solution, use trial and error reasoning, overcome frustration when pieces of the puzzle do not fit, and finally complete the puzzle. A student attempting to complete an exeriment such as finding out what affects the boiling point of water would have to try to visualize all the possible variables, set up an experimental design, and begin to use trial and error reasoning to test each variable. During the experiment, students may be frustrated when test designs do not work out and they must start again. If the student is able to keep hypothesizing and testing, the correct answers to the lab may be discovered. The trial and error reasoning of process science is one small component, but because of possible similarities between the process science, a puzzle test was designed and tested. See appendix D for a copy of the puzzle test.

The puzzle test consists of a letter of the alphabet, like a T or an H, that is cut into pieces. The students must assemble the pieces to form the correct letter. The first trial of the test proved too difficult for the students. Students were not told that it was a letter of the alphabet. The only instruction given was that the pieces went together to form a shape they would be familiar with. After five minutes they were told that it was a letter of the alphabet, and after five more minutes, they were told what letter of the alphabet it was. The letter H puzzle given had too many pieces and was too difficult for the students to assemble. The design of the test was also too difficult. By the time the students found out what the letter was, they were too frustrated to use good trial and error reasoning. A second puzzle test was developed. The design of this test was:

Pass out puzzle pieces of a very simple letter like the letter T. Solving this puzzle required the students to put together four pieces. Students were instructed that it was a letter in the alphabet, and they would have five minutes to work on it. If they arrived at the answer they should raise their hand, and it would be checked. At the end of five minutes, students were told what letter of the alphabet it was, and they would have five more minutes to solve it. This letter was collected at the end of the time period, and the procedure was repeated with a more difficult letter. In this study, another version of the letter H was used. This H was more difficult than the T puzzle, having more pieces, and a more complicated pattern. The same testing procedure was used as with the T puzzle.

The scoring procedure on the puzzle test was a one to ten number rating. A one meant the student solved the puzzle in the about one minute and a ten meant the student solved the puzzle in about ten minutes. Puzzle test were designed and used as another means of identifying strong potential exploratory lab learners. Along with all the other instruments and tests, they would represent another profile of students' problem solving abilities.

IOWA BASICS

In order to study the academic achievement of students, the Iowa Tests of Basic Skills was used. It was necessary to compare test scores to see if there was any relationship between academic achievement as measured by the Iowa Basics, lab process skills and lab learning styles. Do students having high Iowa Basic science scores do well in lab process test? Would these students be Type I students on a lab learning style inventory? To help answer these questions, Form G of the Iowa Basic science test was given. This version of the test consists of forty-five objective questions in all disciplines of science. The questions fall into all domains of Bloom's Taxonomy of higher level thinking skills, and many of the questions contain interpretation skills necessary for process science. A student may be shown a chart of some data collected during an experiment, and asked to make some interpretations of the data. This type of question is similar to one that students may have to deal with in any lab experiment. The National Percentile Norm (NPR) for science was recorded for use in the study. The Iowa Basic tests were used as one means to study the students' overall academic achievements. In addition to science skills, the students are tested on language skills, work-study skills and mathematical skills. All of these test scores are combined for a composite score. A high composite score would indicate that the student is strong in all academic areas. Would this student have a high science score, and how would this student's score compare to scores for the process skills or lab learning style? Thus the NPR composite score for each student was also recorded.

The Iowa Basic test provides an instrument which is standardized jointly with the Cognitive Abilities Test, and the Tests of Achievement and Proficiency. The validity and content specifications are based upon over forty years of continuous research in science curriculum, measurement procedures, and interpretations and use of test results. The internal consistency reliability coefficients range from .84 - .96. This test is often cited nationally in research on science education.

STUDENTS' SCIENCE GRADES

In this study, the researcher's classroom science grades for students were recorded and used. The students' science grades are based on a grading system which sometimes takes effort into account as much as ability. Students not satisfied with their science test scores, could do extra projects or labs to help their grades. Many students who are not good test takers work very hard and therefore achieve a high science grade. For this reason, science grades could not be used alone to measure academic ability. The science scores were recorded and used in the study for comparison purposes. These science grades, combined with all the other academic data, would aid in interpreting some findings in the study.

At the conclusion of each science unit, a unit test is given. These tests comprise fifty multiple choice questions in all levels of Bloom's Taxonomy. Each grade level receives approximately five unit tests each year. Students' scores on these unit tests are fairly consistent. A student that scored a 52% on the

Chemistry unit test was usually in the 50% range in the Heat and Electricity unit tests. There were a few exceptions to this, situations in which a student who really enjoyed a particular unit or had a lot of previous background with the material might score higher than the average for that student's other test scores. When this occurred, it was noted in the data chart. The science unit tests provided another instrument to show academic strength. Academic ability sometimes allowed students to attain a high grade in science, but not necessarily perform well in exploratory lab situations.

MIDDLE SCHOOL COMPOSITE GRADES

In addition to science grades, students' classroom grades for social studies, English, and math were combined for a middle school composite grade. Middle school composite grades were used so comparisons between achievement in science and in other subject areas could be made. Would students score high classroom grades in science, but low grades in math or social studies? Composite grades would combine with other data to give a more complete picture of student achievement. Interviews and four years of working experience with the other classroom teachers reveal that their grading systems also take into account the efforts of the students. All of these teachers have extra credit grades which students can use to supplement their classroom grades. Middle school composite scores and science classroom grades were converted from a letter grade to a number grade by assigning an "A" forty points, a "B" thirty points, a "C" twenty-points and a "D" ten points.

SELF ASSESSMENT SURVEYS

What learning style do students perceive for themselves? How do students perceive their own exploratory lab learning abilities, or their ability to solve puzzles? How creative do students feel they are? Do students like exploratory labs? Did it help students to know what style of lab learner they were? Did they agree with these surveys? These, and other questions pertaining to students' perceptions of their process lab abilities and preferences became the focus of the self assessment surveys. Before each lab activity, the students were given a self assessment survey form (Appendix E). At the conclusion of each task, students were again asked their opinion of how they performed on the activity. Most of the surveys were in the form of a Likert survey. A question or statement was given, and students were asked to circle the response, Strongly Agree, Agree, Uncertain, Disagree or Strongly Disagree. On each of the surveys, students were asked to write down comments about the activity they just completed. An example of this procedure can be illustrated by describing the self assessment procedure used in the lab learning style survey. Several days after the lab learning style survey was administered, students were given descriptions of the various learning style types. Each type was described, and students had the opportunity to read and hear about how each learning style type functioned in the lab. A survey form was passed out, and students were asked which lab learning style type they thought they were. Their individual lab style surveys were then passed back to them, and students could compare their perceived score with their actual score. A post survey form completed the process. This form asked students to indicate how accurate the survey's assessment of their lab learning style was.

This self assessment survey process was used throughout the study. Self assessment surveys reflect student opinions of how accurate they thought the results were. Self assessment provided the researcher an insight into students' perceptions of themselves. Some students thought they performed well on a test, when actually they did not. Other students seemed to have low self-esteem in that they continually thought they were not good at activities, when actually they scored high on those activities.

A student's lab learning styles, exploratory lab process skills, academic ability, creativity and puzzle solving ability were investigated using the instruments and methods described above. Is there any relationship between them, and how can any relationship be used to help improve student performance and understanding? The statistics needed to show any relationship become the focus of the next section.

STATISTICAL METHODS

An important step in developing the Lab Learning Style Instrument was to arrive at a score which would set the Type I learners apart from the Type II learners. The survey was given to ninety seven students and the score was tabulated for each of the three types of learners. A standard deviation was taken and this was 5.2. This standard deviation remained approximately the same for all lab learning style types, and for all populations of students tested. The standard deviation always fell between 4.8 and 5.4. It was decided that a standard deviation of five would be used for all types taking the Learning Style Inventory. The mean of the learning style types varied with the particular type.

Type I and Type III students' means fell between 33 and 37, depending on the class tested, while the Type II students' means fell between 28 and 33. A frequency distribution chart (appendix F) showed a mean of 35 for the Type I and III students and a mean of 30 for the Type II students. Combining the means with the standard deviation of five provides the scoring system used to determine the learning style type of the student.

Scoring system to determine learning style type

Avoidance of Type		Strength of Type
Type I	Below 30	Above 40
Type II	Below 25	Above 35
Type III	Below 30	Above 40
Type IV	Should students not show a strength in any one of the above types, they would be a Type IV.	

A style strength indicates that students in that type show a strong preference towards characteristics of that lab learning style. A strength in a Type III category means the student prefers working with people as compared to working with the lab equipment. A style avoidance means the student does not prefer characteristics in that learning style. A student that shows a style avoidance in a Type III category may be one that might have difficulty selecting their own lab partner. The social interaction is one they do not prefer.

The purpose of this study was to identify and describe relationships between learning styles and exploratory science performance. How are lab process skills related to learning styles? How is creativity related to lab process skill? How is academic achievement related to lab process ability? What is the correlation between any of these areas? Since the data was ordinal, for example when comparison was being made between creativity rank and lab process rank, Spearman 's coefficient of rank correlation was the non-parametric statistic used. This statistic revealed if two variables such as lab process skills and creativity were related. Other correlation statistics were applied to the data, and values agreed with Spearman results.

In some cases in the study, a lab learning style type mean score was contrasted and compared. Checking the significant level of these mean scores required use of a t-test.

POPULATIONS STUDIED

Information was gathered from ninety-seven seventh and eighth graders from Manhattan School District. The Manhattan School system is comprised of middle class families, half of which commute to work in Bozeman, and the other half earn their living in Manhattan or in small ranches and farms in the surrounding area. The students who attend Manhattan schools are generally conservative, hard working students that value their education, and it is not uncommon to have over half the students on the honor roll.

The Lab Learning style survey was tested on another four hundred middle school or junior high age students from a variety of schools and communities.

Eighty-five students were from the Monforton School district. Once again parents work either in a small town environment or on outlying farms and ranches. These students were in the 6th, 7th and 8th grade. These students were instructed by a teacher that used inquiry based, hands-on science.

Two hundred and fifty students were from Linglestown Jr. High School (L.J.H.S.) in Harrisburg, Pa.. These 7th, 8th and 9th grade students were from an urban environment, and were taught by three different teachers. One of the teachers was an inquiry based, hands-on science teacher and the other two used a lecture, textbook format.

Seventy-five students were from Susquehanna, Pa. (Susqu.). Both of these 7th and 9th grade classes were taught by a teacher who used a lecture, textbook, demonstration approach to teaching. The students were from a rural environment very similar to Manhattan, Mt..

Using existing, tested instrumentation, four types of science lab learners were identified. A single instrument was then developed and tested to identify each of these four types. The ability of students to perform exploratory science activities was assessed using several instruments. A combination of nationally used science exploratory process labs and classroom developed process labs was used to assess each individual student's process skills. Process skills were further tested by considering the students' ability to solve puzzles and to test the students creativity. Once the lab learning style and process skill ability were known, students could be matched with other student lab partners to study the effects of different learning styles and exploratory lab teams.

CHAPTER IV

ANALYSIS OF RESULTS

What were the results of the study? This chapter analyzes the results of the data gathered with each of the instruments, and also compares and contrasts the data from each source.

LAB LEARNING STYLE INSTRUMENT

The Lab Learning Style Instrument (LLSI) was developed to assess each student's lab learning type. The LLSI was administered to over five hundred students from six different schools, four different grade levels and eight different teachers. Once the test was administered and scored, it was possible to determine whether a student was a Type I, Type II, Type III or Type IV lab learner. What is the relationship between different populations, grade levels and various lab learning types? Would different teachers influence the lab learning type preferences of their students? How would learning styles be affected by gender? To analyze these questions, two outcomes of the LLSI were considered.

(1) The arithmetic mean for each learning style type, and the standard deviation. A base line for each type was established by using a frequency distribution (See appendix F). Scores which are outside the base line would indicate strengths or weaknesses in the learning style type.

TABLE 2
SCORING CHART FOR LAB LEARNING STYLE INVENTORY

Lab Learning Style Types	Mean	Standard Deviation	A style avoidance	A style strength
TYPE I	35	5	Scores of 29 or lower	Scores of 41 or higher
TYPE II	30	5	Scores of 25 or lower	Scores of 36 or higher
TYPE III	35	5	Scores of 29 or lower	Scores of 41 or higher
TYPE IV	Scores 30 - 35			

The average mean and the standard deviation for each type, was consistent for all groups which took the LLSI. With the exception of a few groups, t-tests performed on the LLSI Means did not show any significant difference when tested at a .05 confidence level. An extremely high style strength would be two standard deviations above the average. Two standard deviations below the average would indicate a low score or a style avoidance. When testing lab process work involving partners, an attempt was made to match a student's style strength with another student's style avoidance (table 2).

The mean and standard deviation for each grade is found in appendix G. This data indicates that there is not any significant lab learning style difference with regard to various populations. Urban school populations such as Linglestown (L.J.H.S.) and rural school populations such as Manhattan (Man) both have similar mean scores in all learning style types. In some populations there is a slight increase in the mean for type III female students.

When comparing the various schools and teachers one finds similar mean scores in all learning style types. There is an occasional group such as Monforton's eighth grade class whose males had a mean of 40 in the type II or Manhattan's eighth grade female group that had a mean of 40 in the type III category. Most groups attained similar means in each of the lab learning style types. This leads to the conclusion that based on this study, school, type population or teacher does not affect the distribution of the students' preferences across lab learning style types.

(2) A second method of learning style analysis compared classroom percentages of each learning style type. What percent of a typical classroom is Type I , II or III learners? What percent of females or males are Type I, II or III learners? The chart lists the percents of males and females in each category of the four grades studied.

TABLE 3

GENDER PERCENTAGE CHART COMPARING VARIOUS LEARNING STYLE TYPES FROM MANHATTAN MIDDLE SCHOOL

		TYPE I	TYPE II	TYPE III	TYPE IV
6TH	FEMALE N=37	20.5%	20.5%	15.4%	43.6%
	MALE N=37	5.6%	52.8%	19.4%	22.2%
7TH	FEMALE N=59	5.2%	19.0%	24.1%	51.7%
	MALE N=104	15.5%	30.1%	17.5%	36.9%
8TH	FEMALE N=57	10.2%	27.1%	49.2%	13.6%
	MALE N=36	10.3%	41.0%	20.5%	28.2%
9TH	FEMALE N=57	15.8%	17.5%	38.6%	28.1%
	MALE N=71	19.7%	29.6%	23.9%	26.8%

The largest gender discrepancy in percents occurs in the Type II and Type III learning style lab preferences (table 3). In each of the four grades, there were more males that preferred Type II styles than females. This might indicate that males seem to prefer working with the equipment more than the females. In the 6th grade, a nearly equal percent of male and female students were Type III. In 7th, 8th and 9th grades there was a higher percentage of females choosing the Type III learning style. This percent increased in 7th grade and climaxed in 8th grade then began to drop in 9th grade. This might indicate that female students throughout middle school have stronger preferences concerning lab partners and social surroundings than their male counterparts. This social activity seems to begin at the end of the 6th grade and climax in the 8th grade.

Lab learning preferences can also be compared across the four grade levels studied. What changes are there in the relative percentages of the four learning style types across these grades?

The lowest percentage of students belonged to the Type I style (table 4). This suggests that for the majority of middle school students their main preference is not "getting the answers right on a lab activity." It is interesting to note that the percentage of Type I students in 6th grade (14.9%) is comparatively high, then drops off throughout 7th and 8th grade (12.0% and 11.6% respectively), and finally increases to the highest level in 9th grade (17.8%). This data might suggest that students in 6th grade prefer to do lab activities which are organized and structured, and these students are concerned about a right answer on the lab. The preference of the 7th and 8th grader is not in this Type I style. By 9th grade, preferences return to being concerned with "getting the right answer on labs."

The number of Type II percents started quite high in 6th grade (33.8%) and gradually dropped off (22.5%). A possible reason for this might be that 6th graders are either anticipating working with science equipment (Manhattan's 6th graders) or else just started working with the science equipment (Monforton's 6th graders). As the novelty of using the equipment wears off, the students' desire to use the equipment lowers. The percents would therefore gradually drop. It should be noted that even the lowest preference for Type II (22.5% in 9th grade), is still relatively high in terms of the other lab learning styles.

The percentages for the Type III social learners increased from 16.2% in 6th grade to a high of 39.3% in 8th grade, before dropping off slightly to 30.2% in 9th grade. Students throughout middle school appear to be very social and peer conscious, and this may be reflected in their LLSI scores.

The Type IV learners do not have a definite learning style, and should the LLSI be administered again, many of the Type IV learners would be listed as Type I, II or III learners. The lab learning styles for some of these students seemed to change daily or weekly. These students did not have a definite learning style. There was also a group of students whose learning style remained very consistent. These students became known and studied as **stable lab learning style students.**

STABLE LAB LEARNING STYLE STUDENTS

Stable lab learners are those students who have the same learning style type for months or even years. Stable lab learners were identified in a four stage process.

(1) An initial LLSI was administered to eighty-one middle school students at Manhattan, and their lab learning style was recorded.

(2) Several weeks later the student copy of "Learning Styles in Exploratory Lab Students" (Chapter III) was passed out, and the students were given the opportunity to read a description of the four lab learning styles.

TABLE 4

PERCENT LEARNING STYLE TYPES FROM EACH MIDDLE SCHOOL GRADE IN ALL SCHOOLS SAMPLED

	TYPE I	TYPE II	TYPE III	TYPE IV
6TH GRADE (N=74)	14.9%	33.8%	16.2%	35.1%
7TH GRADE (N=327)	12.0%	29.5%	23.4%	35.1%
8TH GRADE (N=123)	11.6%	27.7%	39.3%	21.4%
9TH GRADE (N=129)	17.8%	22.5%	30.2%	29.5%

Students were surveyed (See appendix H) as to which of the four types they thought they were. The initial LLSI was passed back so each student could see what type the inventory listed them as. Thirty percent of the students had picked the exact same learning style. One of the types is a Type IV which is a combination of the other three types. It would be possible for a student to select a Type III on this self-assessment survey, yet on the inventory he may score a 39 in the Type III category, a 29 in the Type II category and a 34 in the Type I category. The inventory scoring would list this student as a Type IV, yet he would be very close to the Type III selected in the self-assessment. A Type IV student could have an LLSI score very close to that of a Type I, II or III student. Taking into account such borderline cases, eighty-one percent of the students recorded the same learning style on the self-assessment as shown on the LLSI.

(3) Does lab learning style types remain constant? Would a student have the same learning style type six weeks later? To answer these questions, the LLSI was administered to the same 81 students six months later at a different time of day and day of the week. Fifty-seven percent showed no change in lab learning style type, and an additional 34% retested as Type IV's with scores very close to that necessary for their prior designation as Type I's, II's, or III's.

(4) Another lab learning style survey was developed. This was a teacher recorded survey form (See appendix I). The teacher would assess the student's lab learning style. The teacher survey requires the teacher to answer questions based upon the teacher's observation of the student. As in the LLSI, the scores are tabulated and one of four lab learning style types is assigned. A Pearson Product correlation performed between the initial LLSI test and the teacher inventory was .82. The teacher inventory is useful because some students have a skewed perception of themselves. They answer the LLSI inventory NOT how they are, but rather how they want to be. The teacher

inventory helps to place a more accurate picture on student lab learning styles.

Stable lab learning style students were defined as students whose first and second LLSI scores, self-assessment scores and teacher inventory scores were all the same. Only Type I, II, and III learners were considered. A student possessing a consistent Type IV was not considered. A "Type IV factor" was considered in 23% of the cases. Students who showed the same lab learning type on three of the measures, and who were Type IV on the fourth measure were labeled as stable lab learning style students. The study group had ninety-seven students and forty-four of these students were strong lab learning style students. Across all four classes studied, between 30 to 50 percent of the students had definite lab learning styles which remained fairly consistent. The other 50 to 70 percent of the students in each class had style preferences that changed during the six month period between the initial and final LLSI testings. The forty-four stable lab learning style students became the focus of the rest of the study. If style has any effect on lab work, that effect would be found in students with a definite strong style.

LAB PROCESS SKILLS

The lab process work in this study focused on five process skill tests (table 5). Two of the tests were designed by the researcher, and three of the tests were from the Second International Science Study (Kanis, Doran & Jacobson, 1990). The two researcher designed tests were administered to 8th grades in two classes, and the three SISS tests were administered to 7th and 8th graders in a total of four classes, so population numbers are smaller for these tests. The results of all five process skill tests are listed in the appendix. The process skill tests used in the research had a number of limitations (See Chapter V), but some important findings nonetheless resulted from these tests.

The percents represent the top process score achievers. High achievers on the chemistry practicum were students with a 90% or higher. High achievers on the electricity test were those earning a five or six (a six was the highest possible score). A high achiever on the Dino Nest and Chemistry tests was is a student scoring a four or five (out of a possible five). Students scoring a three on the heat test were listed as high achievers (three was the maximum). To understand how the percentages in the table work, consider this example. Eighty-six percent of the Type I learners scored high on the electricity process test which meant that six of the seven students achieved a high lab process score. Sixty-four percent (or 9 out of 14) Type II students attained a high score on the electricity test, while 87% (20 in all) of the Type III students were high scorers on the same test.

Initial inspection of the table would indicate that Type I and Type III learners seem to have the highest percentages of high scorers on the five process skill tests. That may suggest that the strongest process learners in these tests are the Type I and Type III learners. One needs to take a closer look before making this statement.

The Type I and Type III categories included a larger percentage of 8th graders the Type II category. These 8th graders had one more year of instruction in process science, plus the added maturity of an extra year. The emphasis of this group's middle school science instruction was process/ exploratory science. Students were taught how to define problems, formulate hypotheses, design and carry out experiments and make conclusions. The outcomes of this instruction may have been revealed in the higher process scores attained by the 8th graders as shown above.

It is interesting to note that students of all lab learning types scored relatively high scores on certain process tests. The Type I's were among the highest scorers in the electricity process and heat process tests. The Type II's did well on the heat process and chemistry process, and the Type III's on the chemistry practicum and electricity process. Regardless of the lab learning style type there is success in process oriented exploratory science.

According to the SISS manual the heat process test is oriented toward the reasoning component of lab process science. Of the three possible scoring points in the lab, two are for the students ability to reason. This is the highest point value for any of the reasoning components of the SISS test. It was one test on which even the Type II 7th graders scored relatively high.

The data shown in the table also makes a good statement for social learning in lab teams. The chemistry unit is taught mainly through lab oriented science. Students work in lab teams to discover the principles and concepts of chemistry. They are tested two ways: an objective multiple choice exam and a chemistry lab practicum. Both exams are performed by the individual student. The 31% of the Type III lab learners scoring high on the chemistry practicum may indicate that this social method of instruction is valuable for them. The low 17% of the Type I learners scoring high on the same practicum may indicate that cooperative methods do not work as well for this group. The large number of Type III learners in middle school science supports the need for social, process science activities.

Research in the process work of lab science reveals that all learning types perform reasonably well in different areas of process science. The amount of instruction and experience in process science may be more important than learning style type. Despite their lack of experience and instruction, Type II students in this study showed relatively strong reasoning skills. Type III students individually learn a great deal by being able to work cooperatively. This cooperative effort does not seem as significant on Type I learners.

TABLE 5

PERCENTAGE OF HIGH ACHIEVERS IN EACH LEARNING STYLE TYPE FROM MANHATTAN MIDDLE SCHOOL

Lab learning style types	Percent students in each grade.	SISS electricity process test. (1)	Chemistry Practicum exam - teacher designed (2)	Dino Nest process test - teacher designed (3)	SISS heat process test (4)	SISS chemistry process test (5)
TYPE I	86% - 8th 14% - 7th	86% (N=7)	17% (N=6)	33% (N=6)	71% (N=7)	29% (N=7)
TYPE II	36% - 8th 64% - 7th	64% (N=14)	Did not take test	Did not take test	57% (N=14)	38% (N=14)
TYPE III	57% - 8th 43% - 7th	87% (N=23)	31% (N=13)	31% (N=13)	39% (N=23)	68% (N=23)

(1) A high achiever must have a score of 5 or 6 out of a possible 6.
(2) A high achiever must have a 160 points out of a possible 200 points.
(3) A high achiever must have a 4 or 5 out of a possible 5.
(4) A high achiever must have a 3 out of a possible 3.
(5) A high achiever must have a 6 out of a possible 6.

What are the results when students of different learning styles become lab partners? Would a Type II learner working with a Type III learner produce better results than two Type III learners working together? When given the choice of lab partners, is there any particular learning style partner which students select? Are Type I learners the preferred lab partner of other students? To answer these questions, research was designed with various combinations of lab partners completing process labs together (table 6).

Process labs on density, electricity and human biology were used. In the electricity lab, students were assigned to a person having the same learning style. A Type I was assigned to work with another Type I student. Some Type I learners were assigned to work with Type II or III learners. In the bone lab students were assigned to a partner of a differing learning style. Some Type I learners were assigned to work with Type II or III learners. When this exploratory lab was performed in the 8th grade, there were not enough Type II learners to assign to mixed pairs. For this reason, there were not any student lab groups for the Type II learners. Students were allowed to pick their own partner for the density lab. Data was collected and recorded regarding the learning style of their selection, plus the results of the process lab. Survey forms asking students' opinions of their lab partners were administered at the conclusion of the activity.

The inconsistencies of lab process assessment instruments are discussed in Chapter V. This phase of the research clearly demonstrates this. There is a large difference in the group means for each of the different process tests. This difference is due mainly to the varying difficulty of the process test. A difficult process test like the density test, has a relatively low group mean. For comparison purposes, the group mean and standard deviation was taken. The maximum score on the density lab was 6 with a group mean of 2.6.
The maximum score on the bone lab was 5 with a group mean of 3.9. The

easiest process test was the electricity test with a maximum score of 5, a group mean of 4.7, and a small standard deviation of .7 because of the consistently high scores attained by the students. Most students scored very high, not because of the research treatment, but rather because of the difficulty level of the particular process test. A t-test applied to these means does not reveal any significant differences between the means of the three process tests. Using these process tests for comparison purposes however, allows one to make several observations.

In most of the individual process test scores from Table 5, the Type I students scored very well. Two Type I students do not necessarily make a strong or weak team. The social preference (Type III) students seem to score well when allowed to work with another student they have chosen themselves. This is supported by the fact that the lab learning type with the greatest percentage of high scorers on the density lab was Type III (table 6). The density lab was a lab in which students were allowed to choose any partner. The Type III students chose mainly other Type III partners. The Type I and Type II students did not appear to follow any particular pattern when selecting partners. The Type I and Type II students seem to score higher on the process tests when they were assigned a lab partner. When partners were assigned by the researcher, an effort was made to create mixed pairs in which each student worked with someone of a different lab learning type. All possible combinations of mixed pairs were used. The Type III students seem to score comparatively higher when they were allowed to chose their own partners. A question on the survey form (See appendix E for data results on survey form) dealt with students choice of lab partner. Students' were asked which they preferred, (1) choosing their own partner, (2) being assigned a partner or (3) choice did not matter.

TABLE 6

RESULTS OF LEARNING STYLE TYPES WORKING WITH LAB PARTNERS FROM MANHATTAN MIDDLE SCHOOL

LEARNING STYLE TYPES	MEAN SCORES OF LAB STUDENTS		
	Students choose their partners (Density lab)	Students assigned their partners (Electricity lab)	Students assigned their partners (Bone lab)
TYPE I	2.6 (N=14)	5.0 (N=12)	5.0 (N=6)
TYPE II	2.4 (N=10)	5.0 (N=6)	No student lab groups
TYPE III	3.08 (N=24)	4.5 (N=24)	3.0 (N=10)
GROUP MEAN (+,-) STANDARD DEVIATION	2.6 (N=48) (+,-) 1.5	4.7 (N=42) (+,-) 1.7	3.9 (N=16) (+,-) 1.5

Of the Type I students, 33% preferred to be assigned a partner, and 67% said it did not matter. None of the twelve students preferred to choose a partner themselves. Of the Type II students 100% stated that it did not matter whether they were assigned or chose a partner. Of the Type III students, 17% preferred to have a partner assigned, 58% said it did not matter, and 25% preferred to choose their own partner. Type III was the only group in which a substantial number of students preferred to choose. Although these differences were not statistically significant, it is interesting that the Type I and II students scored slightly higher in process labs when assigned to a lab partner, and the Type III students preferred to select their own partner, and performed better with this partner.

CREATIVITY AND PUZZLE SOLVING

Often in exploratory lab process science, creativity becomes an important component. What is the relationship between creativity and the various learning style types? Is one learning style type more creative than another?

The mean, standard deviation and range on the Torrance creativity test and the researcher-designed puzzle test were used to describe and compare the groups (table 7) . A low standard deviation and range meant that there was a higher percentage of students closer to the mean.

Comparing the mean creativity percentile for each of the lab learning types, one can see that the Type II students scored highest with a mean of 62, and the Type I students scored lowest with a Mean of 38 (table 8). A t-test revealed that the creativity means of the Type I students were significantly different than the whole group mean at a confidence level of .025. The mean of the Type II students was significantly different than the whole group mean at a confidence level of .01. The mean of the Type III students was not significantly different than the whole group average.

TABLE 7
CREATIVITY AND PUZZLE CHART FOR MANHATTAN MIDDLE SCHOOL STUDENTS

LEARNING STYLE TYPES	MEAN SCORE, (+,-) STANDARD DEVIATION, (RANGE)		
	CREATIVITY PERCENTILE (Torrance Test)	CREATIVE STANDARD SCORE (Torrance Test)	PUZZLE TEST (Researcher designed test) (Min.)
TYPE I (N=7)	38 (+,-)12, (8, 68)	84 (+,-)18, (34, 134)	8.7 (+,-)2.8, (1.7, 10)
TYPE II (N=13)	62 (+,-)13, (18, 106)	107 (+,-)9, (78, 136)	9.6 (+,-)2.9, (1.6, 10)
TYPE III (N=22)	50 (+,-)19, (0, 112)	100 (+,-)15, (48, 152)	8.5 (+,-)3.7 (0, 10)
GROUP (N=42)	51 (+,-)19, (0, 132)	99 (+,-)15, (11, 179)	8.7 (+,-)3.5, (0, 10)

This data indicate that Type II students are relatively creative, and Type I students are less creative. The Type III students' creativity level falls between the other two groups. The standard deviation of 13 for the Type II students indicates that most of the Type II students are more creative than the average Type I student. How creative are the Type II students, and how weak in creativity are the Type I students?

The standard score for creativity provided in Table 7 shows how each group's score compares to normative scores from the Torrance Test. A standard score below 80 would indicate an especially weak creativity score and a score above 120 would indicate an especially strong creativity score. The Type I students are close to this bottom 80 with their 84 standard score. The Type II students as a group are above average, but not especially strong with their 107 score. The entire group of 42 Type I, II and III students tested represent the normal population in that their mean score was a 99 as a group. Of all the people taking the Torrance Test, 100 is the group mean. Once again, the relatively small standard deviation of 9 and the low range of 29 indicate that this Type II group as a whole attained higher creativity scores than the other two groups.

The puzzle test is a timed activity. Students are given a time limit to solve a puzzle. The lower the numerical score, the less time it took the student to solve the puzzle, and the better the student would have done on the test. The means for the number of minutes needed by Type I, II and III students to solve the puzzle were 8.7, 9.6, and 8.7 respectively (table 7). A t-test performed on the three means indicate that there is not any significant difference between the means of the three types.

Even though this researcher-designed test had several revisions, as an instrument it was not sensitive enough to detect any differences that might be

TABLE 8

SPEARMEN RANK CORRELATION CHART OF ACHIEVEMENT TEST RESULTS FROM MANHATTAN MIDDLE SCHOOL STUDENTS

Science test scores and Science class grades. (N=37)	.506
Science test scores and Iowa Basic Science Test Scores. (N=37)	.624
Science test scores and Iowa Composite scores. (N=37)	.671
Iowa Basic Science Test Scores and Iowa Composite scores. (N=37)	.801
Iowa Composite Scores and Jr. High Composite Scores. (N=37)	.738

present between various lab learning style types. Students were given a survey before and after the puzzle test pertaining to their frustration or enjoyment levels, and their perceptions of their own abilities to solve puzzles

Prior to solving the puzzle, 86% of the Type I students stated that they liked solving puzzles. The Type I students enjoyed the highest success rate of all the groups with 57% of the students in this group solving the puzzle. The next highest success rate was 38% for the Type III students. When surveyed after the puzzle test, only 29% of the Type I students stated that they liked solving puzzles. Even though this group had the highest percentage liking puzzles prior to the activity, and enjoyed the greatest success rate, they also were more prone to become frustrated with the puzzle experience. The other groups did not have the negative post-activity reaction displayed by the Type I's. This may be an indication of a characteristic of Type I lab learners. They prefer structure, organization and good grades. Even when they achieve good grades, if these grades are not perfect or near perfect, the Type I lab learner may not like that activity anymore. Science teachers may encounter this when working on process labs with Type I learners. Perfect answers are rare when involved in the area of experimentation. Type I learners may feel they are not getting all the answers right, and express frustration over this.

ACADEMIC ACHIEVEMENT

How well students performed on standardized tests and what grades students earned is the focus of the academic section. Is there any relationship between lab learning style type and academic achievement?

TABLE 9

A COMPARISON OF LAB LEARNING STYLES, STANDARDIZED AND SCIENCE TESTS, SCIENCE AND COMPOSITE CLASSROOM GRADES FROM MANHATTAN STUDENTS.

INSTRUMENT OF EVALUATION	MEAN SCORES, (+,-) STANDARD DEVIATION			
	STABLE TYPE LAB LEARNERS			MANHATTAN MIDDLE SCHOOL STUDENTS (N= 97)
	TYPE I (N=7)	TYPE II (N=13)	TYPE III (N=23)	
IOWA BASIC COMPOSITE SCORES	81.9 * (+,-) 17.7	61.8 (+,-) 24.2	60.3 (+,-) 26.2	64.3 (+,-) 27.1
IOWA BASIC SCIENCE SCORES	85.3 * ** (+,-) 12.6	70.2 (+,-) 26.6	59.75 (+,-) 30.8	67.0 (+,-) 28.5
SCIENCE TEST SCORES (1)	143.4 (+,-) 23.1	140.9 * (+,-) 24.3	130.3 (+,-) 21.8	127.6 (+,-) 22.9
MIDDLE SCHOOL COMPOSITE GRADES (2)	38.3 * ** (+,-) 2.2	25.2 * ** (+,-) 8.9	31.7 (+,-) 8.1	30.1 (+,-) 9.5
SCIENCE CLASSROOM GRADES (3)	38.9 * ** (+,-) 3.0	23.2 (+,-) 13.1	28.6 (+,-) 12.6	28.6 (+,-) 12.6
CREATIVITY SCORES (TORRANCE TEST)	38.2 * ** (+,-) 11.5	61.9 * ** (+,-) 13.1	50.0 (+,-) 19.4	51.0 (+,-) 19.1

(1) The average of three 200 point unit science tests covering classroom content.
(2) The yearly average of English, social studies and math classroom grades.
(3) The yearly average of science classroom grades.

* SIGNIFICANTLY DIFFERENT WHEN COMPARED TO ENTIRE POPULATON AT .025 CONFIDENCE LEVEL.
** SIGNIFICANTLY DIFFERENT WHEN COMPARED TO STABLE LEARNERS' AT .05 CONFIDENCE LEVEL.

TABLE 10
SUMMARY OF THESIS RESEARCH

RESEARCH AREA	LAB LEARNING STYLE TYPES		
	TYPE I	**TYPE II**	**TYPE III**
LLSI instrument data	This group may comprise the lowest percentage of the students in a class	This group will be in between the other two groups in size.	This group may comprise the highest percentage of students in a class.
Individual process test work	Wide range of performance levels.	Wide range of performance levels.	Wide range of performance levels.
Lab partner process work.	Prefer activity and score higher when assigned a lab partner.	Prefer activity and score higher when assigned a lab partner.	Prefer activity and score higher when allowed to choose own lab partner.
Creatvity - As measured by the Torrance Test.	Lower than national norms.	Higher than national norms.	Almost identical to national norms.
Academic Work	Strong - This group scores well in both classroom work and standardized tests.	Weak in classroom work, but higher on standardized tests.	Average
Other comments	Can become frustrated if they do not attain perfect or near perfect scores. They may verbalize this frustration by saying they do not like the activity.	Score much higher on tests than classroom grades. Retain a lot of information from the science class.	Are very sociable and peer conscious, but learn a lot individually by working together.

To answer this question, five achievement areas were studied.

(1) Science test grade scores for large tests covering each unit. These objective multiple choice tests covered material taught in class, and presented in the textbook. They served as an indication of students' note taking ability and/or comprehension ability. A student who listens very closely in class may score high on these tests.

(2) Science class grades included the science test scores, as well as homework activities, lab work, extra credit work and any other graded activities. A student who was not satisfied with his or her test score could do extra credit work to raise his grade. The science class grade was based on effort as much as ability.

(3) The Iowa Basic Science test was the standardized science test used.

(4) The Iowa Composite scores represents the language art score combined with a math and social studies score.

(5) The Middle School Composite score is an average of the students' math, social studies, science and English grades for one year. This average was taken at the conclusion of the 1992-93 school year. The first item to consider was any correlation which may exist between any of the five areas. A Spearmen Rank Correlation was performed on each of the five areas. The resulting data is shown in the table (table 8).

Some of the correlations, such as that between science test scores and science class grades were not very significant (.506). Nonetheless, all the correlation results are listed to demonstrate how much variance there is in student performance on academic assessments. It is interesting that there is a high correlation between the Iowa Basic Science test and Iowa Composite scores. A student who scores well on a standardized achievement test will probably do well whether the test is science, social studies or math. Mean scores on each assessment were analyzed according to lab learning style types, and a t-test was applied to find any significant relationships. The chart presents the results for the Iowa Basic composite and Iowa Basic science scores, the middle school composite of grades and the middle school science grade (Table 9).

A number of interesting results can be observed in the charts. The Type I students preform very well on academic assessments. In each of the four areas their performance surpassed that of the Type II and Type III students, and the differences were significant at the .0005 to .025 level. Their highest scores compared to the other groups were in the middle school classroom composite grades (table 9). Success in the form of high academic achievements is important to a Type I student, and the scores clearly illustrate this. Classroom grades in the Middle School Composites are based as much on effort as ability. Scores indicate that Type II students were not as concerned about academic success. They were below the mean at significant levels of .05 as compared to the population of students completing the Middle School Composite. Sixty-two percent of this group received a failing grade in one or more of their four middle school subjects. Type II students have average scores on the standardized assessments. Type II students also score at relatively high levels on science tests (table 9).

Comparing the Type II mean science test scores with the population mean reveals that Type II students academically perform higher than the population (confidence level at .05). This group of students often have a high course failure rate, yet demonstrate ability when given an achievement test or an objective classroom science test. In this researcher's observations, the discipline and attitude necessary to complete classroom assignments often are lacking.

An organized, logical way to summarize this chapter is to chart the results as they relate to each lab learning style (table 10).

My initial hypotheses for the thesis stated:

Learning styles have an effect on lab process science, and this effect can be measured.

Based upon my research, I have found that lab process science is difficult to assess reliably. By comparing student percents for each of the process tests, it becomes possible to measure lab process success. For example, if 52% percent of the Type I students score high in the electricity process test, and 35% of the Type III students score high, one can make a comparison between the two groups. The research in this study found that all types of learning styles performed well on various process labs, and it was not the learning style type which determined process lab success.

A second hypothesis stated:

By considering student learning styles during the lab design, teachers can increase student performance.

The study indicated that process lab success increased when students were allowed to work together in partners as opposed to individually. The lab teams were the strongest when learning styles were considered. The Type I and Type II students either preferred to have a lab partner assigned to them or else it did not matter to them who their partner was. When this preference was followed, science process scores increased. The Type III students preferred to choose their own partner, and they usually chose other Type III students. When allowed to work in these conditions, the lab performance scores increased.

Student learning styles become an important lab design when choosing lab partners. Students of different learning style types provide an excellent source of lab partners with varying pre-dispositions in a science classroom. By strategically arranging these combinations, the teacher can encourage stronger performances from students in science labs.

A goal of this study was to develop a lab learning style instrument which would give science teachers a relatively accurate, fast, and inexpensive assessment of students' learning style. The goal was accomplished and the learning style assessment was piloted with hundreds of middle school science students.

CHAPTER V

DISCUSSION OF RESULTS

The aim of this study was to study learning styles and process science. Some relationships between students' learning styles and process science performance were identified, and methods were developed and piloted for gathering learning style information, then using it to help students with science labs. As the study progressed, a need was established to look at other areas potentially related to lab process science. Creativity, puzzle solving skills, classroom grades and standardized achievement test scores were identified as areas which might relate to process science and learning styles. Whenever new categories were studied, new questions developed from the data collected. Despite the unanswered questions and limitations, this study provided many insights into helping students with process science work.

SUMMARY AND DISCUSSION OF FINDINGS

A science lab learning style assessment instrument was a goal of this study. Using four existing learning style instruments, a Lab Learning Style Instrument (LLSI) was developed and piloted with hundreds of middle school students from varied communities, schools and classrooms. This instrument identified each student as one of four types of lab learners. Administration of the new learning style instrument developed in this study required about fifteen minutes of class time, and cost almost nothing. Other widely used learning style assessments do not focus on learning styles for science labs, take forty-five minutes to administer, and may cost hundreds of dollars to score oneself or to have scoring done by the supplier. The LLSI provides reliable data that any middle school teacher in almost any setting could use to profile their students. The study determined that not all students have a definite learning style that remains constant. In the four classes studied, 30 to 50 percent of the students had a learning style that was constant during a six month period. Of that group, the Type I students comprised the smallest percentage, and the Type III students made up the largest percentage. Type III's were the students that preferred the social interaction of the science lab. This social preference had some positive results. For example, the Type III learners performed well compared to absolute standards and to other groups during activities such as the chemistry lab practicum and the density process lab that involved significant social interaction. These social learners preferred to work together and scored significantly higher as individuals when allowed to do so.

A second learning style assessment developed was a teacher's inventory. A survey form was filled out by the instructor based on observations of the student and the student's work. This teacher's inventory assessed the student's lab learning style based upon the teacher's observations. This inventory was only piloted by the researcher with his own students. Time was not available to test this instrument with other science teachers. A limitation of the teacher's inventory was that filling it out required experience working with the student. It would be difficult to fill an inventory out for a new student the first week of school. In this study, the teacher's inventory was developed and tested after the initial LLSI inventory results were known, so there was the possibility of teacher researcher bias.

Research with the lab process work reveals there is not any significant difference in lab process scores and lab learning styles. A significant difference was found when looking at grade level and process lab performance. The eighth graders consistently scored higher on lab process work than the seventh graders. This may be due to maturation or instruction. Most of the eighth graders tested had one more year of instruction in process oriented science.

Three of the process labs in the study had lab partners of different lab learning styles working together. Slight increases in the mean performance levels were found when Type III learners were allowed to choose their own lab partners. Slight increases in the mean performance levels were found when Type I and Type II learners were assigned a lab partner. The learning style type of the assigned lab partner did not seem to have any effect on the score.

The creativity of each student was assessed using the Torrance Test of Creative Skills. While the Type III students recorded a near average standard score of 99, the Type II students were significantly higher than the national average and the Type I students significantly lower. None of the groups would be classified as extremely high or low in creativity.

The puzzle test was designed as a possible instrument to assess students' abilities to accomplish trial and error learning. The presumption was that students who were good at putting a puzzle together would have the patience and ability to solve experimental science labs. While the puzzle test did not accomplish this purpose, it pointed out a fascinating characteristic of Type I students. Prior to the puzzle test, the Type I students expressed the highest interest in solving puzzles. During the test, the Type I students had the highest success rate of solving the puzzles, yet after the test they had the highest frustration level of any of the three types. Even though this group experienced success, they were not able to attain the perfect scores or clear cut sucess they desired. Throughout the researcher's years of experience teaching process oriented science, it was observed that some students repeatedly became frustrated during exploratory process science activities. The researcher assumed that this group of students lacked the skills for process science. The puzzle test opens up the possibility that these students may have the necessary skills, but because they are not getting easy or perfect answers, they become frustrated. Real process science and experimentation rarely have a single perfect answer.

This study also looked at classroom students' scores on class activities, and their course grades and their standardized achievement test scores. As might be expected, the Type I students did well in all of these areas. This type of student prefers structure, organization and good grades. The Type II students seem to have relatively strong ability as shown by their high standardized test scores and science test scores, but may lack a degree of motivation and effort as shown by their low classroom grades. Type III students perform in the average range of classroom grades and on standardized tests.

INTEGRATION AND IMPLICATIONS OF FINDINGS

How can results from this study help classroom science teachers? A sheet prepared for science teachers titled "Learning Styles and Science Lab Work" (appendix J) was given to teachers interested in using lab learning style information to improve students' science lab work. Teachers could use the information on this sheet to help them utilize learning style information in lab work.

A number of important points are brought up in the paper, "Learning Styles and Science Lab Work." These points were supported by this research study.

(1) Learning styles can be identified, but only a small percent of the students in a typical classroom have stable learning styles which remain the same for long periods of time.

(2) The largest percentage of students in the middle school classrooms studied were the Type III learners. The Type II students comprised the next largest group, and the Type I learners the smallest group.

(3) There was not any relationship between a particular lab learning type and overall ability to do process labs. All types had strong lab learners and weak lab learners.

(4) There was a positive relationship with performance when students worked in pairs on lab activities vs. working individually. Students working in lab teams scored higher than students working individually.

(5) There was a relationship between the preferences of lab partners from the different learning styles and there was an improvement when Type III learners were allowed to work with other Type III learners. Some Type I and II learners preferred to have lab partners assigned, while others did not care whether partners were chosen by students or assigned. Type III learners preferred to choose their own lab partners.

(6) One characteristic of Type I learners is that they express frustration when not achieving a perfect score on a science lab. Even though this group obtains as many right answers as other students, when their work is not perfect, they express frustration. The open ended nature of process science often has many unanswered questions, resulting in frustration for this group.

This frustration should not be interpreted as the Type I's having less ability to succeed in process science. Often they arrive at correct answers through a correct process, yet the open ended nature of lab work frustrates them.

(7) The Type I learners are less creative than the Type II learners. A possible explanation for this might be time is spent by Type I learners organizing and structuring activities, and Type II learners use this time to think of alternate ways to carry out the activities. When Type II learners are asked to draw thirty different pictures with a set of two parallel lines, (Torrance Test) it is easy for this group, but not for the Type I's. There was not a significant relationship between standardized creativity scores and process lab performance.

(8) Type I learners show high achievement in classroom grades and on standardized tests. Type II students have high scores on standardized tests and classroom tests if the classroom tests are based on daily class activities. The Type II students often do not turn in assignments or follow through with out-of-class activities, so their grades are the lowest of any group.

RECOMMENDATIONS FOR FURTHER STUDY

Frequently a study generates more questions than it answers, and that is the situation with this study. This study is a pilot effort to investigate relationships between students' lab learning styles, process lab performance, creativity, standardized test performance and classroom grades. An attempt was made to find any relationships between these four areas. In some cases clear relationships could not be established, perhaps because more research is needed on these broad areas.

The study and development of the LLSI attempted to utilize the format and findings of existing learning style research. It was not the intent to create a different category of learning style for the science lab, but rather to take the existing learning style framework and apply it to science lab students. The LLSI instrument needs further development and study. It was administered a second time to students six months later. What would be the LLSI results from these students one year later? The hundred students at Manhattan school indicated on questionnaires that learning style information helped them. How do other students in other schools feel about the value of learning style information? Do they feel it is accurate and helpful? How do high school students', or adults' learning style types compare to middle school students'? How can other teachers utilize lab learning style information in their science classes? These are just some of the questions that need additional research.

The area of process science is one that this researcher feels needs extensive additional work. Some goals for this study were not met, due to inadequacies in lab process assessment instruments. If the instrumentation does not produce reliable and valid results, the data collected are of questionable value. The link between students' process lab work and their learning styles was not investigated in classrooms other than the researcher's for this reason. Increasing the use of process science or "hands-on" science in the schools is a goal that has been adopted in many states. It is an area that will require the development of reliable and valid instrumentation. How can teachers measure the effects of a process science curriculum if they lack adequate assessment tools? This researcher recommends the following steps:

(1) Provide a complete synthesis and analysis of the current research in process science. In chapter II of this paper one can find Reiffs' Learning Style Profile. The profile represents a synthesis of learning style research. The same type of synthesis needs to be done with process science research. How do all the terminology and findings from research on process science fit together? Once all the research is synthesized, instrumentation needs to be developed.

(2) Develop instrumentation needed to assess the various lab process skills. This instrumentation needs to be reliable, valid and sensitive to accurate measurement of lab process skills. The SSIS process tests made the best attempt at dividing process skills into components such as reasoning ability or design ability, but the tests were not reliable or sensitive enough. Students would score high in one reasoning test, and low in the next. The Torrance Test of Creative Thinking lists a raw score and standard score, but also divides creativity into thirteen components. Lab process assessments may have the same format with students performing a lab activity which has many different science process lab components. Assessment of the student's lab work would indicate which lab components the student was strong or weak in. A student may be skilled at designing a lab, but weak in developing predictions from lab results. Research and development are needed in process science assessment before one can establish treatments to help improve students' process skills.

One item which may become part of the science lab process synthesis is creativity. How does creativity relate to process science performance? Intuitively, one would think that a Thomas Edison or Marie Curie would be a creative person. How would they score on a Torrance Test? Can a test be designed to measure the types of creativity scientists use? One would assume that an assessment could be made of scientific creativity and that students could be taught ways to develop their creativity during science lab.

The questions become endless and each new research finding brings many new questions. The important issue becomes that we as a society keep asking questions and trying to discover answers to these questions. It is this questioning and discovering process that is the heart of good science, and contributes toward a better society.

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APPENDICES

APPENDIX A

MODIFIED SWASSING BARBE MODALITY INDEX

MODIFIED SWASSING-BARBE MODALITY INDEX

This index will help you learn about some of your major ways of thinking. There are not any right answers. You are to read the question and put an 'M' (most frequently used) behind the answer which you like the best. If, there is a second response which you use a lot, just not as much as the main response, put an 'S' (second most frequently used).

I. Reading
- ___ a. I enjoy it, I'm a strong reader and have always been successful. I'm a fast reader.
- ___ b. I attack words well, enjoy reading aloud and listening. I'm not very fast.
- ___ c. I like action-packed stories, in fact, I often jerk and move when reading.

II. Spelling
- ___ a. It is easy for me, unless I have never seen the word before.
- ___ b. I use the phonetic approach and spell in a sing-song rhythmic pattern.
- ___ c. I am weak and tend to count out the letters with foot tapping or head bobbing.

III. Hand writing
- ___ a. having it look well is important; learning neatness was easy.
- ___ b. I tend to talk to my self as I write.
- ___ c. Mine isn't as good as others; it is usually thicker because I press harder.

IV. Types of verbs used
- ___ a. I use the following a lot: see, picture, vision, clear, focus, foggy.
- ___ b. I use the following a lot: hear, sounds like, rings a bell, out of rhythm.
- ___ c. I use the following a lot: grasp, hold, let go, do it, got it, handle it.

V. Memory
- ___ a. It is easier for me to remember faces than names.
- ___ b. It is easier for me to remember names than faces.
- ___ c. I remember what was done, better than who's face or name was involved.

VI. Favorite expressions
- ___ a. "I see what you mean.", "Do you get the picture?", "Is that clear?"
- ___ b. "I hear you.", "Does that sound right?", "Thankyou for listening."
- ___ c. "I can handle it.", "Does that feel right?", "Got it."

VII. Fantasizing

___ a. I see vivid imagery; can picture future possibilities and details.
___ b. I hear sounds and voices.
___ c. I want to get up and actually act out the imagery; walk through the idea.

VIII. Conversations

___ a. I have to have the whole picture with the details, and when explaining I sometimes wander off on tangents.
___ b. I am more talkative than others; love discussions and sometimes I monopolize.
___ c. I am a toucher when I talk; I use gestures, movement and lots of action words.

IX. The method of learning

___ a. I need an over-all view and purpose with a picture of details.
___ b. I like to talk about the alternatives by dialoguing both to myself and others.
___ c. I learn by touching, handling, manipulating and actually doing.

X. When bored

___ a. I stare, daydream, notice small items around myself, shapes and colors are noticed.
___ b. I hum, sing or talk to myself; get people into conversations.
___ c. I have to move, find something to touch or hold, otherwise I just fidget.

XI. Voice

___ a. I usually speak with my chin slightly raised and my voice is high.
___ b. I shift my tone and tempo to "mark off" important points.
___ c. I usually speak with my chin slightly lowered and my voice deeper.

XII. As I have been answering these questions: (Eye scanning patterns)

___ a. My eyes have been above eye level as I search for impressions.
___ b. My eyes have been eye level.
___ c. My eyes have been down and to the same side that I am "handed".

Tabulate: "a" choices above are Visual; "b" are Auditory; and "c" are Kinesthetic tendencies. Total all the "M" and "S" for each modality to determine ranking of your strengths.

"A" choices: number of "M"_____, number of "S"_____
"B" choices: number of "M"_____, number of "S"_____
"C" choices: number of "M"_____, number of "S"_____

APPENDIX B

MODIFIED MYERS-BRIGGS INVENTORY

THINKING AND LEARNING STYLE PREFERENCE SURVEY
LEVEL II

Name______________________________ Male____ Female____

School______________________________ Grade__________

Birthdate: Month__________ Day__________ Year__________

Which hand do you use to write? Right ________ Left ________

Cultural orientation ______________________________

For each of the following statements rank them from four (4) to one (1). Mark the one that is the most like you 4, then a 3, then a 2, and the one least like you a 1.

1. I like to read books:

   about people. . . . . ☐

   with action stories. . . . . ☐

   with fantasy or science fiction stories. . . . . ☐

   about real events . . . . ☐

2. I'd rather study:

   by myself without being bothered . . . . ☐

   by myself at the same time every day . . . . ☐

   with other friends or in a group of students . . . . . . ☐

   when I have a lot of short assignments. . . . . ☐

3. I like to:

   work fast and finish first. . . . . ☐

   work carefully so I can get it right. . . . . ☐

   talk about what I'm studying. . . . . ☐

   think about an assignment before I do it. . . . . ☐

4. I like to:

   be the leader in our group. . . . . ☐

   think up ideas for our group. . . . . ☐

   make sure we follow the instructions. . . . . ☐

   help the others in our group. . . . . ☐

5. I want our group:

to do it right. ☐

to have fun . . . . ☐

to get the best grade . . . . ☐

to do something different . . . . ☐

6. I want to:

know exactly what to do and how to do it. . . . . ☐

figure it out for myself. . . . . ☐

have someone helping me work. . . . . ☐

tell others what to do and how to do it . . . . ☐

7. When I work on an activity or project I want:

to work with other students. . . . . ☐

it to be neat and correct. . . . . ☐

to have something to take home when I finish . . . . ☐

it to be different and creative . . . . ☐

8. When I am given a project assignment I want:

to help others in our group. . . . . ☐

to know exactly how to do it . . . . ☐

a project that doesn't take too long . . . . ☐

want to come up with my own project ideas. . . . . ☐

9. When I talk with others I:

get irritated when they ask for too many details. . . . . ☐

don't listen if they don't know what they are talking about. . . . . ☐

want to get started right away . . . . ☐

want to talk about what I'm doing. . . . . ☐

10. When I don't get my way:

    my feelings are hurt . . . . ☐

    I insist my way is best. . . . . ☐

    want to hit someone or break something . . . . ☐

    go off by myself. . . . . ☐

11. Some people may think that I am:

    moody . . . . ☐

    too neat and organized. . . . . ☐

    always trying to be first or to win . . . . ☐

    a daydreamer . . . . ☐

12. When I have a writing assignment I:

    have to think about it before I write it. . . . . ☐

    work best with an outline and check for errors. . ☐

    want to write as little as possible. . . . . ☐

    want someone to help me and write about
    something I know. . . . . ☐

13. When people don't agree with me I:

    think they don't like me . . . . ☐

    tell them the facts and use logic . . . . ☐

    want to argue for my ideas. ☐

    don't care and do it my way. . . . . ☐

14. When I think of time, I:

    like spending lots of time with people. . . . . ☐

    like to stay on schedule. . . . . ☐

    like to hurry and finish first. . . . . ☐

    forget what time it is if I am really
    interested in what I'm doing . . . . ☐

15. When I meet new kids, I

take my time getting to know them. . . . . ☐

let them come to me . . . . ☐

like to tell them what to do . . . . ☐

get them involved in our activities . . . . ☐

16.When talking to kids I don't know, I want them to:

think that I am friendly. . . . . ☐

think I'm smart. ☐

think I'm the leader . . . . ☐

think I'm creative . . . . ☐

17. When I'm nervous in front of others, I:

act kind of different and silly. . . . . ☐

get "up-tight" . . . . ☐

show-off. . . . . ☐

get confused. . . . . ☐

18. I feel happy when I:

get lots of things done. . . . . ☐

am liked by other kids . . . . ☐

solve a hard problem and get a good grade. . . . ☐

come up with new ideas. ☐

19. I can change other kids' minds when I:

talk them into it. ☐

give them the facts. . . . . ☐

can tell them "why" . . . . ☐

can show them how. . . . . ☐

20. When everything goes wrong, I:

    try to get help. . . . . ☐

    feel guilty . . . . ☐

    get mad. . . . . ☐

    try to ignore the problems . . . . ☐

21. When others criticize me, I:

    get my feelings hurt. . . . . ☐

    keep doing it my way because it's quicker . . . . ☐

    try to get it right . . . . ☐

    go off by myself and avoid them. . . . . ☐

22. When I have a problem, I ask myself:

    what is the quickest way to fix it. . . . . ☐

    what's the problem and then check the facts . . . ☐

    who is to blame for the problem. . . . . ☐

    ignore the problem or daydream a solution. . . . . . . ☐

23. When we're talking about something I really like, I:

    stick to the details and want to tell it right . ☐

    want to do most of the talking. . . . . ☐

    forget about everything else. . . . . ☐

    tell why I like it and how I feel about it. . . . . . ☐

24. I think that sometimes I:

    talk too much and correct other people. . . . . . ☐

    am too loud and bossy. . . . . ☐

    am too friendly and trusting . . . . ☐

    am too quiet because I don't know what to say. . . . . ☐

T F S I

APPENDIX C

LAB LEARNING STYLE INSTRUMENT

INSTRUCTIONS FOR ADMINISTRATION OF LLSI

The accuracy of this survey is partly determined by administration of it, so your participation is greatly appreciated.

Some general ideas might be:

(1) Students that can't read would not have any meaningful results. You may want to allow these students to take it, but please note on their survey form, that they have difficulty reading.

(2) Although it is not always possible, the survey is best administered on a morning either Tues., Wed. or Thurs. Again, this is not always possible.

(3) It will require the students about 15 minutes of time to complete the survey. They could use pencil or pen.

WHEN THE TEST IS ADMINISTERED

(1) Pass out the test. Explain to the students that this is a survey, to try to help them find the different ways that they learn science. Explain that **there are not any right answers.** We all learn differently and there isn't a right or wrong way to learn. There isn't a right or wrong answer on the survey. They should attempt to answer the questions honestly as the question pertains to them.

(2) The student should read the questions and each of the three answers. The answer that the student feels is most like them, they should put a 3 in the box. The answer that is second most like them, they should place a 2 in the box, and a 1 in the box that they like the least. **You should emphasize that a 3 goes in the box they like the MOST, and a 1 in the one they like the LEAST.** Many students may reverse this if it isn't stressed.

(3) At the completion of the test, the student should add all the numbers in the first column on all the pages. This sum would be written in the blank at the end labeled # 1. They should repeat this with the second column of boxes and total this sum in the end blank # 2. Repeat with the third column. The total of all the end blanks should be 102. This is a good check for the students' to use on their math.

LAB LEARNING STYLE INVENTORY

BY WALT WOOLBAUGH

For each of the following statements, rank them from a three (3) which you like the best, a two (2) which you like second best to a one (1) which you like the least. There are not any right answers so be honest.

1. When doing a science lab:

   I like to work with the equipment...................... ☐

   I like to work with a lab partner......................... ☐

   I like to get anwsers right on the lab................. ☐

2. Before I begin working on a science lab:

   I would like to find out who my lab partner is..... ☐

   I would like to see what equipment we will use.. ☐

   I would like to find out what my teacher expects from us for the lab...................................... ☐

3. When someone gives me a suggestion, I:

   Check with someone else to see if it might be right... .... ☐

   Think about it myself to see if it might be right... ☐

   Consider the suggestion and try several possibilities... ☐

4. When solving a puzzle:

   I try one piece, if that doesn't fit, I try another... ☐

   I try to find a picture or solution to the puzzle.... ☐

   I like to work on puzzles with other people........ ☐

5. Regarding the classes I like in school

I like classes where the teacher explains just what we need to get an A.. ☐

I like classes where we get to figure things out for ourselves... ☐

I like classes where we get to work with other people.. ☐

6. If I am doing a science lab, and I get stuck with a problem, I :

Go on to the next problem and come back .... ☐

Ask one of my friends to help me................................ ☐

Ask the teacher to help me.. ☐

7. I like to:

Talk about what I'm studying............................... ☐

Work carefully so I can get it right........................ ☐

Work fast to get it done so I can do something else.. ☐

8. Some people may think that I am:

Too neat and organized....................................... ☐

Too concerned about other peoples' feelings........... ☐

More interested in doing activities than listening about activities.. ☐

9. When I have a writing assignment I:

Want to write as little as possible........................ ☐

Work best with an outline and check for errors.. ☐

Want to work with other people on the assignment.. ☐

10. When I think of time, I:

Like spending lots of time with people............... ☐

Like to stay on schedule.................................. ☐

Forget what time it is if I am really interested in what I'm doing... ☐

11. I want my lab team to:

Get the best grade.. ☐

Do something different and creative.................. ☐

Get along with each other................................. ☐

12. I think people would chose me for a lab partner because:

I'm a nice person that people like...................... ☐

I have alot of good ideas to work in a lab........... ☐

I get good grades... ☐

13. When I'm talking to somebody I don't know, I want them to:

Think that I am friendly..................................... ☐

Think that I am smart....................................... ☐

Think that I am creative.................................... ☐

14. I feel happy when I:

Get lots of things done... ☐

Am liked by other people .... ☐

Solve a hard problem and get a good grade........... ☐

15. When I make something in the lab, I like to:

Work with others.. ☐

Follow the directions... ☐

Do it my own way... ☐

16. If I am working on a science lab, and I got stuck on one of the experiments, I would:

Figure it out myself.. ☐

Ask my lab partner... ☐

Ask the teacher.. ☐

17. I like science classes:

Where we work with a lab partner.......................... ☐

Where we have to figure out how to do a science experiment... ☐

Where the science labs are written out step by step ☐

TOTAL FOR EACH OF THE THREE COLUMNS _____ _____ _____

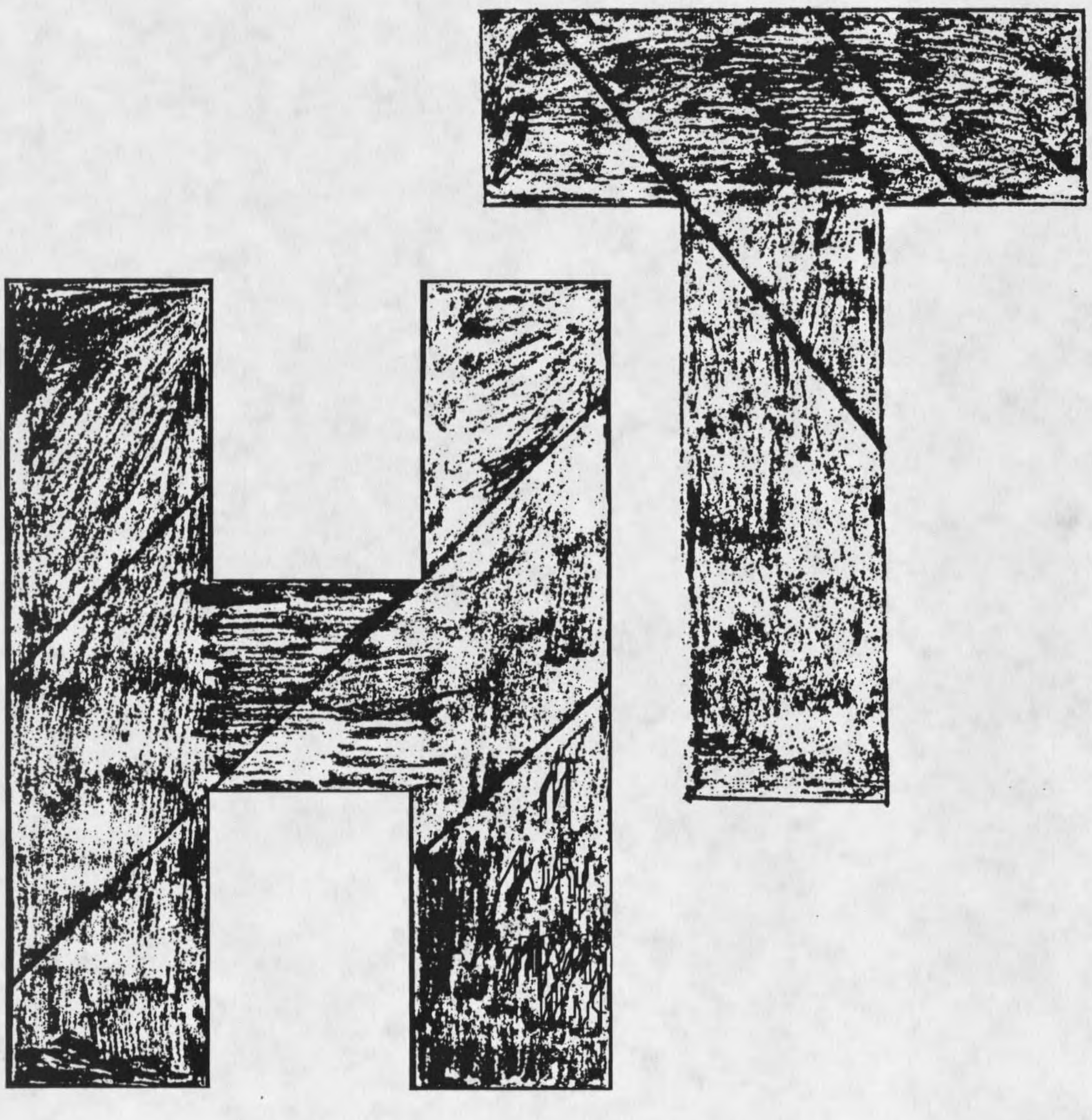
1 2 3

APPENDIX D

PUZZLE TEST

PUZZLE TEST

Students were given pieces of the "T" puzzle. They were told it formed a letter in the alphabet. After five minutes, students were instructed that it was the letter "T". At the ten minute mark, the test ended. The time it took students to solve the puzzle was recorded. The test was repeated with the letter "H."



APPENDIX E

SELF-ASSESSMENT SURVEY FORMS

STUDENT SURVEY FORMS

Throughout the study, students' were surveyed as to their opinions on the activities. A sample of these survey forms are listed.

NAME ____________

(Exploratory lab)

SURVEY FORM

CIRCLE THE LETTER WHICH BEST DESCRIBES YOUR OPINION OF EACH STATEMENT. **SD** = strongly disagree, **D** = disagree, **U** = uncertain, **A** = agree, **SA** = strongly agree.

1. I like to figure out how to do science labs.	**SD**	**D**	**U**	**A**	**SA**
2. I'm not very good at figuring out science labs.	**SD**	**D**	**U**	**A**	**SA**
3. I don't get frustrated easily.	**SD**	**D**	**U**	**A**	**SA**
4. I enjoy science labs where we get to heat objects.	**SD**	**D**	**U**	**A**	**SA**

NAME ________________

CIRCLE THE LETTER WHICH BEST DESCRIBES YOUR OPINION OF EACH STATEMENT. **SD** = strongly disagree, **D** = disagree, **U** = uncertain, **A** = agree, **SA** = strongly agree.

1. I enjoyed doing this science lab.	**SD**	**D**	**U**	**A**	**SA**
2. I wasn't very good at this science lab.	**SD**	**D**	**U**	**A**	**SA**
3. I would have rather done this with a lab partner.	**SD**	**D**	**U**	**A**	**SA**
4. I was frustrated during this activity.	**SD**	**D**	**U**	**A**	**SA**
5. This was fun and I'd like to do another lab.	**SD**	**D**	**U**	**A**	**SA**

Any other comments on this activity.

NAME ____________

(Chem. practicum form)

SURVEY FORM

CIRCLE THE LETTER WHICH BEST DESCRIBES YOUR OPINION OF EACH STATEMENT. **SD** = strongly disagree, **D** = disagree, **U** = uncertain, **A** = agree, **SA** = strongly agree.

1. I liked doing this lab practicum	**SD**	**D**	**U**	**A**	**SA**
2. I think I did pretty well on the practicum	**SD**	**D**	**U**	**A**	**SA**
3. I think I would have scored better if I could have worked with someone else.	**SD**	**D**	**U**	**A**	**SA**
4. This was pretty easy	**SD**	**D**	**U**	**A**	**SA**
5. I could have used more directions in doing each activity	**SD**	**D**	**U**	**A**	**SA**
6. I like being tested this way	**SD**	**D**	**U**	**A**	**SA**

NAME ____________

(Lab style survey form)

After you have read the Lab style sheets, please fill out this form.

From your reading of the sheet, what Type do you think you fit in to?

____

Explain why you think this.

After you get your Lab Survey back, answer the below questions.

SURVEY FORM

CIRCLE THE LETTER WHICH BEST DESCRIBES YOUR OPINION OF EACH STATEMENT. **SD** = strongly disagree, **D** = disagree, **U** = uncertain, **A** = agree, **SA** = strongly agree.

1. Overall, I would agree with the Type I am on the survey.	**SD**	**D**	**U**	**A**	**SA**
2. After reading some of the questions over, I would answer questions different today than I did the day of the survey	**SD**	**D**	**U**	**A**	**SA**
3. Overall, I would agree with the Type descriptions.	**SD**	**D**	**U**	**A**	**SA**
4. I found this to be helpful to me in the future.	**SD**	**D**	**U**	**A**	**SA**

Please make some suggestions on how this survey could be improved. Are there any questions that should be changed/adjusted? If so, what questions?

(Puzzle survey form)

ENVELOPE NUMBER _____

NAME _____________

SURVEY FORM

CIRCLE THE LETTER WHICH BEST DESCRIBES YOUR OPINION OF EACH STATEMENT. **SD** = strongly disagree, **D** = disagree, **U** = uncertain, **A** = agree, **SA** = strongly agree.

1. I like to figure out puzzles.	**SD**	**D**	**U**	**A**	**SA**
2. I'm not very good at figuring out puzzles.	**SD**	**D**	**U**	**A**	**SA**
3. I don't get frustrated easily.	**SD**	**D**	**U**	**A**	**SA**

APPENDIX F

FREQUENCY DISTRIBUTION SHOWING HOW LAB LEARNING STYLE SCORES WERE DETERMINED

FREQUENCY DISTRIBUTION USED TO DETERMINE LAB LEARNING STYLE INVENTORY SCORING

A scoring system was needed to score the Lab Learning Style Inventory (LLSI). A group of seventy-five target students were selected. These students were targeted based upon their scores on other learning style inventories such as the Dunn & Dunn Learning Style Inventory. The Modified Barbe-Swassing and a modified Myers - Briggs inventory. These seventy-five students also produced similar results when given the LLSI six months later. A frequency distribution performed on their LLSI test results became the basis for the scoring system used in the LLSI. The mode for the Type I and Type II learners was 35, and the mode for the Type II learners was 32. For scoring purpose, 30 was the score used on the Type II learners.

<u>Scoring system to determine learning style type</u>

	Avoidance of Type	Strength of Type
Type I	Below 30	Above 40
Type II	Below 25	Above 35
Type III	Below 30	Above 40
Type IV	Should the student not show a strength in any one of the three types, they would be a Type IV.	

Throughout the year of testing, over five hundred students from six different schools, four different grade levels and eight different teachers, the above scoring system produced good results. The frequency distributions and modes for the seventy-five students are shown on the next page.

Frequency distribution and modes of Type I, II and III students. Lab Learning Inventory score range, number of sudents within each range, and percentage students are shown.

TYPE I STUDENTS			
SCORES FROM:	SCORES TO:	COUNT	% STUDENTS
29	29.9	1	4
29.9	30.8	2	8
30.8	31.7	2	8
31.7	32.6	2	8
32.6	33.5	4	16
33.5	34.4	4	16
34.4	35.3	5	**20 – MODE**
35.3	36.2	3	12
36.2	37.1	2	8
37.1	38	0	0
TYPE II STUDENTS			
28	29.3	3	12
29.3	30.6	3	12
30.6	31.9	2	8
31.9	33.2	8	**32 – MODE**
33.2	34.5	4	16
34.5	35.8	2	8
37.1	38.4	0	0
38.4	39.7	0	0
39.7	41	1	4
TYPE III STUDENTS			
32	32.9	2	8
32.9	33.8	1	4
33.8	34.7	4	16
34.7	35.6	3	12
35.6	36.5	6	**24 – MODE**
36.5	37.4	3	12
37.4	38.3	2	8
38.3	39.2	2	8
39.2	40.1	2	8
40.1	41	0	0

APPENDIX G

MEAN AND STANDARD DEVIATION FROM THE LAB LEARNING STYLE INSTRUMENT AS ARRANGED BY GRADE LEVELS

MEANS AND STANDARD DEVIATIONS FOR LLSI

		TYPE I	TYPE II	TYPE III
6th grade -Monforton	Mean	33	36	34
Males N=17	Standard Deviation	6	5	6
6th grade - Monforton		34	33	35
Females N=14		4	5	5
6th grade - Manhattan		32	35	35
Males N=20		5	5	6
6th grade - Manhattan		37	30	35
Females N=23		4	4	5
7th grade Monforton		32	34	36
Males N=7		5	3	6
7th grade Monforton		33	33	36
Females N=17		5	5	6
7th grade Susqu.		35	34	33
Males N=31		5	4	4
7th grade Susqu.		34	32	36
Females N=41		4	4	5
7th grade L.J.H.S.		31	34	37
low ability male. N=9		4	6	5
7th grade L.J.H.S.		35	31	36
low ability female N=12		5	3	5
7th grade L.J.H.S.		37	31	34
middle ability male N=15		6	5	8
7th grade L.J.H.S.		36	28	38
middle ability female N=12		5	4	6
8th grade Monforton		30	40	32
Males N=10		6	3	7
8th grade Monforton		33	33	36
females N= 14		6	4	7
8th grade Manhattan		36	33	34
Males N=26		5	7	7
8th grade Manhattan		35	28	40
Females N=16		5	4	8
8th grade L.J.H.S.		29	32	40
high ability N=14		6	6	8

		TYPE I	TYPE II	TYPE III
9th grade Manhattan	Mean	36	30	36
Males N = 30	Standard Deviation	6	6	6
9th grade Manhattan		35	29	38
Females N=27		5	4	5
9th grade L.J.H.S.		30	34	37
middle ability males N=10		5	6	7
9th grade L.J.H.S.		31	33	39
middle ability female N=12		8	4	8
9th grade L.J.H. S.		33	32	37
high ability male N=11		5	5	6
9th grade L.J.H.S.		34	30	39
high ability female N=7		5	3	3
9th grade Susqu.		35	36	32
Males N=20		5	5	4
9th grade Susqu.		34	35	34
Females N=11		3	4	5

APPENDIX H

LEARNING STYLE TYPE PREFERENCE OF LAB PARTNERS

LAB PARTNER PREFERENCE

Students were allowed to choose their own lab partners (Preferred LLSI), and were assigned lab partners. (assigned LLSI). They were also surveyed as to their opinion on a lab partner (Preferred partner).

STUDENT NAMES	PREFERRED LLSI	ASSIGNED LLSI	PREFERRED PARTNER
BRAINARD, K		III	
DAWE, J		III	DOESN'T MATTER
KEIL, J	IV/III		DOESN'T MATTER
MARBURGER, J	IV/II	II	DOESN'T MATTER
MORGAN, Z	II/III	II	I ASSIGN
PAGE, R	III/	II	I ASSIGN
WELCH, R	IV	II	DOESN'T MATTER
ARCHER, J	III/IV	I	DOESN'T MATTER
BOPP, S		II	
CRAIG, J		IV	
ECTON, A		I	
FENDLER, S		II	
GILLESPIE, T		III	
GREEN, R		I	
KALHIER, N		III	
OTT, E	III/IV	I	DOESN'T MATTER
THOMAS, B	IV/II	I	DOESN'T MATTER
TURPIN, K		III	
VANABBEMA, B			
YPMA, O		II	
ANDRIST, A		II	
BAKEBERG, L		II	
BAXTER, C	IV	III/IV	
BIGGS, M		II/III	CHOOSE
BIGGS, S	IV	IV/III	DOESN'T MATTER
BURKE, S	III		DOESN'T MATTER
DEMING, D		II	
DEWITT, T		II	
FEGEL, K		IV	
GRIMSHAW, A	III	IV	CHOOSE
HAMMER, J	III	III/IV	CHOOSE
KAMPS, C	III	IV	I ASSIGN
MCARTHUR, K	III	IV	DOESN'T MATTER
MCMURRAY, B	II	IV	I ASSIGN
MOLYNEAUX, M	IV/I	III	DOESN'T MATTER
PAULSON, K	III	IV/I	DOESN'T MATTER
RAMIREZ, J		I	
THOMAS, E		III	
THORSON, S	III	IV/II	DOESN'T MATTER
TUCKER, D		II	
VANGELDER, K		IV	
VECCA, A	III	IV/III	DOESN'T MATTER
WOODRING, S		II	

APPENDIX I

TEACHER INVENTORY TO ASSESS LEARNING STYLES

LEARNING STYLE INVENTORY

TEACHERS EDITION

Consider your impression and records of a student. Based upon this information, read each statement, and place a three (3) by the answer that is MOST like the student. A two (2) by the statement that is second most like the student and a one (1) by the statement that is least like the student. ONLY ANSWER THOSE QUESTIONS THAT PERTAIN TO YOUR STUDENT. LEAVE THE OTHER QUESTIONS BLANK.

1. The students' hand writing is
   - Neat and organized.......................... ☐
   - Difficult to read................................ ☐
   - About average.................................. ☐

2. When I have observed the students notebook, I found
   - Some extra 'doodling' and other peoples names written on the cover.. ☐
   - The notebook isn't organized, or they don't have a notebook.......... ☐
   - The notebook is organized and most items are in place..................... ☐

3. Concerning the students' homework being turned in:
   - This student doesn't turn alot of assignments in............................ ☐
   - Most assignments are turned in on time.. ☐
   - This student does well on group type assignments............................. ☐

4. While watching the student interact with the class in group activities, I observe:
   - This student prefers to work alone..... ☐
   - This student prefers to work with people.. ☐
   - I don't observe any preference towards either.................................. ☐

5. Before class begins, I observe the student
   - Usually looking around at the equipment or items in the room......... ☐
   - Usually talking with someone else..... ☐
   - Usually getting their notes and materials ready for class................... ☐

6. When this student hands in group assignments, I find:
   - The student has alot of good ideas, but not organized well...................... ☐
   - The student generally writes down what everyone else in the group has written down...................................... ☐
   - Their work is complete and organized ☐

7. During a typical lab activity, I observe the student
   - Setting up and playing with the equipment....................................... ☐
   - Talking with their lab partners........... ☐
   - Wanting to know what to do on their lab to get an A.......................... ☐

8. When this student chooses a partner, I think they would be concerned with:
   - Their partner wouldn't matter, but rather the type of lab they were doing would matter.............................. ☐
   - Their partner wouldn't matter, but rather the grading criteria of the lab would matter.................................... ☐
   - Their first concern would be their lab partner.. ☐

9. At the conclusion of a science period, I observe this student:
   - Getting their materials ready for the next class... ☐
   - Talking with other people as they prepare for the next class........................ ☐
   - Looking at equipment around the room... ☐

10. During an exploratory science lab, this student might:
    - Get side tracked working on another part of the lab...................................... ☐
    - Be concerned that you as a teacher has not provided enough directions........ ☐
    - Be more concerned about their lab partner than the lab................................ ☐

11. When this student gets 'stuck' in a lab situation they most usually
    - Ask their lab partner.............................. ☐
    - Ask you as the teacher.......................... ☐
    - Try different solutions themselves to figure it out.. ☐

12. If this student had a puzzle to solve:
    They would use a trial and error approach to solving it........................ ☐

    They would want to have a partner to help them..................................... ☐

    They would want to know if it was graded.. ☐

13. This student might have a job
    That involves working with people..... ☐

    That involves working with their hands... ☐

    That involves organization and paperwork... ☐

14. When this student gets an assignment back
    They are not real concerned with a grade... ☐

    They are concerned about the grade. ☐

    They are most concerned what their lab partner got for a grade................. ☐

APPENDIX J

INSTRUCTION SHEET FOR TEACHERS "LEARNING STYLES AND SCIENCE LAB WORK"

LEARNING STYLES AND SCIENCE LAB WORK

Teachers work with many different types of personalities throughout science lab work. Understanding and helping students to understand these different types can be beneficial. A way to introduce students to various learning styles might be to administer the Lab Learning Style Instrument (LLSI). Explain to the students there are not any right style. Each of us are unique combining a series of strengths and weaknesses. If we understand ourselves, we are able to capitalize our strengths and work on our weaknesses.

Before passing back the LLSI to the students, have them read the student copy of "Learning Styles in Exploratory Lab Students". After reading about each of the Types, have them write down which Type they feel they are, and why. This step makes them think about the four types, and apply their own characteristics and preferences to these types.

Pass back their LLSI and ask them if they agree or disagree. This step helps them reflect again on characteristics of their learning style, and this sometimes leads to a class discussion about the results. Type I students that prefer good grades and are rewarded for good grades have a difficult time understanding fellow classmates that are not as concerned with good grades. Your discussion probably will not provide any concrete answers, but it is good for other students to be exposed to different view points.

Use the results of the LLSI to help understand your students. A student who has an avoidance in one particular style is one to watch. For example a student that has a 29 or lower in the Type III category may be one that has a difficult time picking and working with a lab partner. This student may enjoy times when lab partners are assigned because the student will not have to go through the stress of choosing a partner. It is also good to note a class that has a high percent of one particular lab learning type. A class with large percents of Type I students may prefer to have material presented in a structured and logical sequence with grade criteria clearly explained.

All three types prefer and perform well in process science. Learning style types are important when working with lab process science, but the most important phase of lab oriented science is the quality of the instruction. Students need to be taught how to define problems, make hypotheses, design and perform experiments, collect data and make conclusions. They need experience, time and practice in a 'hands-on' science class. Middle school students prefer, and therefore are motivated when working with such science labs.

Use the LLSI to occasionally assign lab partners. Sometimes put opposite Types together like a Type I with a Type II or a Type I with a Type III. Sometimes use the LLSI to assign lab partners of the same learning style type. During some lab activities, allow students a choice of lab partners. Type I and Type II learners prefer to have you assign partners. The LLSI will give you a different way to make these assignments. The Type III students prefer, and will usually score higher on, the process labs in which they get to choose the partner. Use a combination of ways to form lab teams, but (1) do use lab teams to perform process labs and (2) attempt to make the focus of your middle school science class process science.

Type I learners often become frustrated during lab activities in which there are not a set of definite answers or the lab activity is quite difficult. In many cases, the Type I learners will be arriving at correct answers, but there may be many right answers, so they tend to become frustrated. Encourage them, and point out how many right answers they have. It would also help them to progressively lead them from a "cook-book" type lab to an exploratory lab which they must design.

Academically, you will find your Type I students performing very well. The Type II learners may perform well on classroom tests and standardized tests, but may not have the organizational skills to turn classroom work or labs in. These Type II learners would benefit by any organization and structure that you could provide. Simple things would help these students like having them keep a notebook, and storing this notebook in the classroom. Then they would not lose the notebook. You will find these Type II learners more creative than their Type I counterparts. Any opportunity you can provide in the classroom to extend the Type I's creativity would be beneficial. An activity like having students develop three more ways a particular experiment could have been done, is an example of an approach to help the students' creativity.

There are many phases to lab process science. One small phase is that of learning styles in the science lab. A teacher who utilizes some of the above suggestions, may help their students have a more rewarding experience in the science lab.