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EFFECTS OF A SPECIALLY DESIGNED PHYSICAL SCIENCE COURSE ON PROSPECTIVE ELEMENTARY TEACHERS' ATTITUDES, KNOWLEDGE AND SKILLS TOWARDS THE LEARNING AND TEACHING OF SCIENCE

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EFFECTS OF A SPECIALLY DESIGNED PHYSICAL SCIENCE COURSE ON PROSPECTIVE ELEMENTARY TEACHERS' ATTITUDES, KNOWLEDGE AND SKILLS TOWARDS THE LEARNING AND TEACHING OF SCIENCE

BY

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ABSTRACT

EFFECTS OF A SPECIALLY DESIGNED PHYSICAL SCIENCE COURSE ON PROSPECTIVE ELEMENTARY TEACHERS' ATTITUDES, KNOWLEDGE AND SKILLS TOWARDS THE LEARNING AND TEACHING OF SCIENCE

BY

James Ernest O'Non

A physical science content course was designed to provide prospective elementary teachers with an integrated learning experience that would: 1) improve their attitude toward science and their ability to learn and teach it, 2) increase their knowledge of selected scientific concepts, and 3) develop their skills and appreciation for learning and teaching science. In delivering the instructional model, staff members placed equal emphasis on these three goals.

A major strategy for achieving these goals was the hands-on laboratory experience where the staff members acted as role models for the type of science teaching that they hoped the prospective elementary teachers would adopt for their own science teaching. Staff members sought to demonstrate qualities of good science teaching through integration of selected attitudes, knowledge and skills.

The research method involved a blend of experimental and ethnographic approaches. The experimental approaches used a pretest-posttest design. These approaches included author developed background-attitude-skills surveys along with

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knowledge questionnaires. The ethnographic approaches included open-ended exercises, interviews and anonymous student written evaluations. Statistical analysis and triangulation were used to determine reliability and validity of the data. The data were used to generate and evaluate assertions whose conclusions were compared with results reported in relevant literature.

The students in this study were typical of prospective elementary teachers. Benefits to students included a large decrease in science anxiety, a large increase in science enjoyment, a large increase in their understanding and application of their new scientific knowledge, and a dramatic improvement in their appreciation and use of specific science learning and teaching skills.

Data from the study suggest that science courses for prospective elementary teachers should combine appropriate instructional modeling, opportunities for active skill development, and supervised practice of specific science content skills. Integration of these elements appears to be of central importance to success in changing students' attitudes, knowledge and skills. Implications for practice and future research are given for pre-service and in-service teacher education and pre-college science education.

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CHAPTER ONE

INTRODUCTION: THE NEED FOR THE RESEARCH

This Research in a Larger Context.

In the past, the American educational system has been given much of the credit for producing and maintaining our world leadership in economic growth, social freedoms, and democratic ideals. Recently, there has been evidence to indicate that the level of scientific literacy in the USA is inadequate for meeting our present and future needs in these areas.

For example, Daedalus, devoted its entire Spring 1983 issue to the subject of scientific literacy. In this issue, Arons stated that our national ability to remain democratic and competitive in a scientific age is being severely tested. Other articles reflected on the diverse aspects of scientific literacy including suggestions for improving science education to meet our national needs.

Various national reports have described both the present deficient condition and the future changes which are needed in the American system of Science Education. Several of the large reports were provided by the National Science Foundation and the National Science Board and will be quoted later. Aware of the implications of these various reports, President Reagan, in his address to the

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National Academies of Sciences and Engineering in May 1982, said:

> The problems today in elementary and secondary school science . . . education are serious . . . enough to compromise America's future ability to develop and advance our traditional industrial base to compete in international marketplaces.

The national reports have revealed that many educators believe that improving the quality of teachers is a major, if not the key aspect to improving our educational system. The National Science Board Report (1983), Educating Americans for the 21st Century emphasizes the vital role of the teacher:

> The teacher is the key to education --- the vital factor in motivating and maintaining student interest in .... science and technology. (NSB Report p. 27)

Several arguments can be made that the improvement of the quality of our elementary teachers may be the most important aspect of the more general challenge of improving the overall effectiveness of science education for the general public. One argument states that even though many young students are naturally curious about the world around them, they are often discouraged with "science" soon after their first educational encounter with it. The National Science Board's Report (1983) issued this statement:

> The evidence is that students entering primary school exhibit a natural curiosity about ....the world around them, but are discouraged from consideration of serious study in these fields early in the elementary grades due to inadequate teaching....(NSB Report p.42)

Eventually the young students become anxious and develop negative attitudes about "science" classes. These early s

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early science anxieties may continue for the rest of their lives, interfering with the development of scientific skills for employment and interfering with the appreciation of the scientific issues that may permeate their lives. In Project Synthesis, Volume 3 (1981) the importance of developing positive attitudes towards science in young students is emphasized:

> During these early years, they form their basic attitudes, patterns of thought, and modes of behavior. It is, therefore, during these years that particular attention must be given to establishing the attitudes and modes of inquiry that are associated with scientific enterprise--- its processes and content. (Harms & Yager, p. 73)

A similar line of argument is that it is easier, if not better to prevent science anxieties by eliminating the factors which cause them early in one's life. One reason emphasized by Bloom in his Stability and Change in Human Characteristics (1964) is that the acquisition of the proper traits early in one's life is significant, if not crucial, because of the sequential nature of human development. Bloom states:

> It is much easier to learn something new than it is to stamp out one set of learned behaviors and replace them by a new set. (Bloom, p.215)

Therefore, it would seem best to engender positive attitudes, knowledge and skills regarding science in the elementary school years. However, many elementary teachers have their own deficiences in these areas. These teaching deficiences may result in ineffective and even negative presentations of science. Poor presentations can occur within any level of our education system, but negative experiences may have a greater and more lasting effect on young children. According to Bloom (1964), the early environment is of crucial importance because it shapes certain human characteristics "in their most rapid periods of formation" (p. 215). Therefore, because the potential for harm is greater with young children, a greater importance should be placed on improving the elementary teacher's science skills so that the children are provided with early science experiences that are both positive and effective.

Many prospective and practicing elementary teachers declare openly that they have anxieties and difficulties with teaching science. Many of them did not enjoy the "science" classes they had as children or young adults. Subsequent experiences seemed to reinforce their anxieties, which result in negative attitudes toward "science" and insecure feelings about teaching it.

It would have been easier, if not better, to have improved the scientific attitudes, knowledge and skills of prospective elementary teachers early in their lives before it became necessary, as Bloom said, to "stamp out one set of learned (negative) behaviors" and try to "replace them by a new (positive) set." In the future, most of these behavior changes should not have to occur if, as children, they have positive science education experiences.

But given the present circumstances of negative elementary and secondary science experiences for many students, the earliest opportunities for improving the scientific attitudes, knowledge and skills of the prospective elementary teachers may not occur until their teacher training programs. However, the national reports have indicated that the existing teacher training programs have not produced the quality of elementary science teachers that America needs.

Many professional educators believe that new teacher training programs are necessary for producing the kind of elementary science teachers America needs. A report from the Science and Math Education staff at Cornell called "Future Directions & Staffing Proposal ..."(1986) states:

> Teacher Education .... has been relatively stagnant; very few new models of training have emerged, and few of the current models include any significant introduction to research on (1) how students learn and (2)the teaching of science.... (Future Directions ...,p. 1)

Lezotte in his "Effective Teacher Training and Urban School Development"(1981) suggests that preservice teacher training needs to be more efficient besides more effective. He believes that teacher educators have a reasonable complaint when they say the typical undergraduate college program does not allow sufficient time for a comprehensive training program. He continues:

> If one accepts the validity of this complaint ... then one would want the training program to be as efficient as possible in order to make maximum use of the time available. If educators and administrators for undergraduate training programs were to recognize the cumulative impact of the prior non-formal training, some

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> curricular content could probably be eliminated and new content added in the areas of demonstrated need. (Lezotte, p. 11)

The Holmes Group report on Tomorrow's Teachers (1986) advocate a greater coordination between methods and content in university teacher training programs. One recommendation is:

> Professional programs need to revised .... Methods and content courses need to be complementary and compatible with one another and develop an ethic of inquiry and professional judgment. (Holmes Group Report, p.55)

Although not designed to specifically address the above opinions about teacher training programs, this specially designed science class may produce some of the qualities of elementary science teachers that have been described by the reports as necessary improvements in science education. For example, this dissertation describes and investigates a specially designed science class which may constitute a component for a new elementary teacher training model, whose need was suggested by the Cornell report and others which now exist. This class may constitute not only an effective but an efficient approach to training elementary science teachers, whose need was suggested by Lezotte. This class may constitute an effective synthesis of science content and teaching methods as advocated by the Holmes Group.

Although not excluding the above needs in the design of this special science class, the staff's conscious objectives were stated from a different, but complementary, view. In promoting better elementary science teaching, the general design of this class tried to encourage in the prospective teachers the development of a positive set of "behaviors" toward science to replace the negative set of "behaviors" learned from their past experiences. The degree of success in reaching this objective would be based on the instructional intentions of the staff in the areas of developing scientific attitudes, knowledge and skills in the prospective teachers and benefits perceived in these areas by the students. The literature review will support the importance that the staff put on these three areas of teacher development.

The author wishes to make clear that the special course design was based primarily on the teaching experience of the staff and their first-hand knowledge of educational principles. The staff was naturally aware of certain knowledge that was available to professional educators. However, the course was not based on an apriori teacher training model. Therefore, this dissertation first attempts to describe and investigate the course as it was, then based on the data, the dissertation infers a teacher training model to interpret the results and to provide a structure for further research.

The concerns expressed by the specially designed physical science course staff in improving the scientific attitudes, knowledge and skills of prospective elementary teachers are consistent with the larger science education community. However, in this specially designed class, the in-

structional intentions were to improve simultaneously--as equal objectives-- the scientific attitudes, knowledge and skills of these prospective elementary teachers. They believed that an effective elementary science teacher must be strong and competent in all three areas.

However, they also believed that a prospective elementary teacher must have a first-hand, positive learning experience that nurtures these areas if the probability of having effective elementary science teachers is going to increase. As one lab instructor named Tom put it, "the way you've been taught something is the way you tend to teach it." This means that if elementary teachers are to exhibit positive scientific attitudes, knowledge and skills in their own teaching, they will most probably need to have experienced a class that contained those qualities within their own learning experience.

Although this is a common idea, many professional science educators seem reluctant to test it in their own teacher training programs. In other words, they do not wish to teach their prospective teachers in a "manner" in which the prospective teachers could use them as a model for their own teaching. This idea of acquiring new patterns of behavior (skills) by watching the performance of others has been given a name. Bandura in his book, Psychological Modeling (1971) calls it the "observational learning effect".

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One's students may have a tendency to use their instructor as a role model regardless of the instructor's willingness to be one. Without some consideration of this possibility by the instructor, a possible unintentional negative influence could result. Recently, the negative influence of role models in science education of teachers was described. Gallagher (1986) mentioned a factor that may account in part for some problems in secondary science teaching. He said:

> Secondary science teachers' role models were university professors who tend to be presenters of information, but who rarely are concerned with students' learning. Typically, the university professors' model of instruction is similar to that observed in secondary schools: present information, give assignments, evaluate performances---good students will learn and the rest will not. When students do not learn or lack motivation, it is perceived as the fault of the students and not the fault of the teachers. (Gallagher, p.9)

Both instructional intentions and role modeling are important components in developing the attitudes, knowledge and skills of an effective teacher training model. However, the scope of development for these three areas in an individual is difficult to evaluate and cannot be measured solely in terms of course design and teaching techniques. A fuller perspective is needed. Therefore, it was essential to include the personal perspectives of the prospective teachers as a part of this research.

<u>A Blend of Experimental & Ethnographic Research Approaches</u>

In order to properly describe and analyze the effects of this specially designed class in terms of its instructional intentions and the perceptions of its students, a

different research plan was needed. This plan involved a blend of statistics and ethnography. Although, historically there has been little collaboration between the proponents of the quantitative and qualitative approaches to research, the author believes that both approaches are complementary in educational research. Science education researchers are beginning to perceive the potential of this blend of approaches. Gallagher (1985) in Looking into Classrooms, recently said:

> Educational ethnographers and experimentalists complement each other's work. Ethnographers can provide the understanding of the 'real world of schools' which can be used by experimentalists as hypotheses worthy of validation or refutation. The experimentalists can subsequently design tests, questionnaires and other instruments which can be examined for reliability and validity and used to acquire data on large and diverse populations of students and teachers. The experimentalists, hopefully, will have hypotheses for testing which are a more accurate portrayal of the reality of schooling. The ethnographers, hopefully will have an additional tool at their disposal for triangulation and increasing the generalizability of their data. Clearly, educational research will be enriched if both methods are used by research teams to strengthen the quality of their research and the usefulness of their findings. (Gallagher, p. 9)

In addition, ethnographic techniques can offer insights into the classroom environment provided by the classroom teacher as researcher. These type of insights could be new and powerful because this approach of the teacher as researcher into his own teaching practices has been denied by the usual research approaches. In his "Qualitative Methods in Research on Teaching"(1986), Erickson offers this view:

> Fieldwork research requires skills of observation, comparison, contrast, and reflection that all humans possess. In order to get through life we must all do interpretative fieldwork. What professional interpretive researchers do is to make use of ordinary skills of observation and reflection in especially systematic and deliberate ways. Classroom teachers can do this as well, by reflecting on their own practice. Their role is not that of a participant observer who comes from the outside world to visit, but of an unusually observant participant who deliberates inside the scene of action. (Erickson, p. 157)

Erickson continues by emphasizing that ethnographic techniques can be considered as a valuable skills possessed by effective teachers. Erickson argues:

> The capacity to reflect critically on one's own practice, and to articulate that reflection to oneself and to others, can be thought of an essential mastery that should be possessed by a master teacher. (Erickson, p.157)

Erickson goes beyond ethnographic techniques as skills of a master teacher to the claim that the employment of this type of research by classroom teachers will strengthen teaching as a profession. He continues:

> If classroom teaching in elementary and secondary schools is to come of age as a profession--if the role of teacher is not ot continue to be institutionally infantilized--then teachers need to take the adult responsibility of investigating their own practice systematically and critically, by methods that are appropriate to their practice....Interpretative research on teaching, conducted by teachers with outside-classroom colleagues to provide both support and challenge, could contribute in no small way to the American schoolteacher's transition to adulthood as a professional. (Erickson, p.157)

The possible benefits and necessary precautions of the observant participant will be discussed later by the author in detail when describing the research design.

The need of this type of research model and research approach in the larger context might be summarized as follows. America needs to improve its science education for a number of good reasons--- economic, social and political. Improvement of the quality of teacher education is a key aspect of this national goal of improving science education. Improving elementary science teaching is a very important part of the general need for improving science teaching. New models for training teachers are needed and then must be researched. In addition, different approaches to research are needed for investigating these models. It now seems appropriate to give a brief qualitative description of the class that encouraged this research.

A Brief Description of Past Students Enrolled in this Class

Some insight into the students' background has been accumulated from past courses through discussions with students and informal surveys. This particular course was intended to be a sophomore class for the prospective elementary teachers. In the past, most of the students did not enroll in this class until their Junior or Senior years. Many of the students would not have enrolled in this class if it had not been a requirement. This is consistent with the subsequent research data in Table 1 in Appendix F, where 87% were juniors or seniors and 72% of the total students would not have enrolled in this class.

In the past, students entering this class have told the instructors that science anxiety played a significant

role in the students not wishing to enroll in this "science" course. Many of the students had already taken their science methods course and some had actually done their student teaching, thereby leaving this as their last class to take before graduation. Other examples of former student negativity towards science had surfaced in previous conversations with the instructors. These former students had used terms like " hateful, too difficult, boring, irrelevant, etc." as descriptive of science. Many of the students related their present anxiety to their previous encounters with "science" classes in education. Some students also felt that their teacher training classes have been inadequate in developing their science learning and teaching skills. How representative are these descriptions of prospective elementary teachers is one reason for this research.

The staff's awareness of general problems in science education and their knowledge of their past students' typical backgounds, motivated them to develop a new class designed especially to meet the preservice training need of prospective elementary teachers. Comments from students about this new class ranged widely, but almost everyone had something positive to say. Examples of comments were:

1) "This is the first time I've enjoyed a science class."

2) "This is one of the best classes I've taken at MSU."

3) "I've really learned some interesting things in this class."

4) "I wish I would've taken this class before my science methods class."

5) "I want to teach science the same way you teach it."

This type of positive feedback and compliments from the students encouraged the staff to continually refine the course in the same direction; that is, to improve the scientific attitudes, knowledge, and skills of the prospective teachers within the same class.

Even though many students had claimed significant benefits regarding their scientific attitudes, knowledge, and skills, no research had been done to describe, understand, or investigate this specially designed course. A brief description of the course structure and the staff's instructional intentions should give the reader a preliminary insight into some of the aspects of this course that led to this research.

A General Description of the Specially Designed Course

Although described as a physical science course for non-scientists, the class was primarily a conceptual physics class required by prospective elementary teachers for their certification. Rigorous mathematical skills were not required for this course. In the ten-week course, five units were covered in approximately two-week blocks. In the five-week summer course, the five units were taught in approximately one-week blocks. The topics were essentially the same in both terms. These topics were waves & sound,

light & color, heat & temperature, electricity & magnetism, and energy & simple machines.

The textbook used was Conceptual Physics (4th Ed.) by Paul G. Hewitt. Hewitt's approach to physics seemed to fit our prospective teachers well. He says:

> .... when the ideas of physics are presented conceptually and when formulas are seen to be guides to thinking rather than recipes for algebraic manipulation, our discipline is accessible to all students. (Hewitt, p. xvii)

His writing style and diagrams were easy for non-scientists to understand. His examples were relevant to daily life. Problems found at the end of the chapters stressed understanding principles and applications.

The laboratory manual was the result of several different individuals, who over the years were a part of the staff for this class. The lab activities were designed to be guided-discovery, hands-on experiences for small lab groups, with some applications to daily life. Many labs were written with the purpose of serving as a future Teacher's Manual in which the prospective teacher could use it as a guide for structuring their own elementary school labs. The understanding of lab concepts were closely coordinated with key concepts being taught in lecture for that particular unit.

Certain course handouts were given to the students before and during a particular unit. They would either outline the major concepts in the unit or give additional information not contained in the textbook or lab manual.

The lecture format involved moderately paced lectures usually having several demonstrations each lecture. There were often opportunities for questions on the material. The professor often solicited discussion by questioning the class. Periodically, short quizzes were given covering that lecture's material. During the ten-week course, the lectures were Monday, Wednesday, and Friday from 3 to 3:50 p.m.. The laboratory format involved a two hour period eachweek followed by a one hour recitation period later in the week. The students had the same instructor for both lab and recitation. Most lab activity was completed during the two hour period, but sometimes it would carry over into recitation. Recitation was used in several ways: problem-set discussions, next week's pre-lab, this week's post-lab, review sessions for the next test, reviewing the last test, and generally giving help when needed.

During the five-week course, lectures were Monday through Thursday for about an hour and a half each day, for a total of about six hours of lecture each week. This was followed each day by a laboratory and recitation activities. The total class time began about 9:10 a.m. and ended about 12:10 p.m..

Staff Objectives for this Course

This Specially Designed Physical Science Course had its objectives in three domains: affective, cognitive and behavioral. It was designed to simultaneously improve the scientific attitudes, knowledge and skills of prospective elementary teachers. Here is a description of some of the staff objectives that were pursued in this course.

The lecture and lab instructors worked together to consciously influence all three domains. An effort to decrease science anxiety was attempted by producing a non-threatening, informal class environment. The lab instructors quickly learned and used the students' first names. Cards with first names on them were used during labs until no longer necessary. On the first day of lab, each student filled out a brief background card giving information about interests, hobbies, and goals.

An important method for monitoring the students' feelings about the course was accomplished through the use of anonymous feedback forms at the end of each two-week unit. In the few minutes after each unit test, the students were asked to list two experiences they liked about the unit and list two experiences they would like to change if given the opportunity. In addition, they were given the opportunity to rate the difficulty of the lecture material, the formality of the lecture presentations, and the pace at which lectures were delivered. Structured reviews and instructors' availability were designed to help to decrease test anxiety. Also, students were strongly encouraged to attend a special review session between the last day of class and the final exam.

In this course, instructors encouraged the acquisition of knowledge by demonstrating a high level of concern for each student progress and a high level of enthusiasm for teaching. Various physics' examples relevant to the students' lives were provided to foster enthusiasm for learning the material and seeing its relevance. Great effort was made by the lab instructors to return corrected material by the next lab session or recitation. It is felt that this effort could exhibit the teachers' high concern and expectations for student progress, allow the teacher to closely monitor that progress, and maximize the materials usefulness and relevance for the student. Activities and tests were designed to emphasize application of knowledge rather than just extending one's vocabulary through memorization so that the student can recall words when the teachers demand it. Test questions emphasized practical applications to life-experiences through the multiple-choice and short-answer approach. In the recitation before each test, a reviewsession was conducted by the lab instructor. A review sheet was given out several days before the review. The lab teacher asked students questions about the review sheets and helped students to answer their own questions. The instructors also were available for meeting with students before and after review sessions if they needed more help.

Science teaching skills were encouraged primarily through the lab experience where each student was asked to reflect on each lab experience as a potential teaching situation for their classroom. Also it was believed that the

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teaching techniques used by the instructors throughout the course in culturing the affective, cognitive and behavioral fields would serve as a resource for developing the students' own teaching skills. The instructors believed that "the way you are taught something is the way that you have a tendency to teach it."

Laboratory Activities Related to the Three Domains

The above instructional intentions could have their most significant effect in the laboratory/recitation part of this course. Here, where the class size should be approximately twenty students, more effective teacher-student interactions were possible.

The affective domain could be greatly influenced by the small, activity-oriented lab groups. In this course no more than 4 students comprised the lab groupings. A hands-on, guided-discovery approach helped maintain a fairly high level of activity. The lab environment attempted to be non-threatening and friendly with emphasis on developing trust toward the instructor and other students. This course encouraged the students to be honest and open when making mistakes and asking questions during their own discovery processes. These "scientific processes" included the development of science inquiry skills such as observing, manipulating, discovering, making tentative conclusions, and discussing their experiences with their small lab group and the instructor.

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The cognitive domain could be encouraged by making strong conceptual connections from the lab activites to lecture and textbook materials. In this course, it was accomplished in part by guiding the students to perceiving underlying principles through specific inquiry lab activities ties and relating them to concepts mentioned in the lectures and textbook. References were made to previous lab activites to further the inter-relatedness of knowledge. The instructors also made conscious references to the students' experiences by showing the relevance of scientific knowledge and thinking skills to the students' daily experiences.

The behavioral field could be nurtured by making conscious references to developing science learning and teaching skills. In this course, the lab manual was designed to become a future teaching resource for the prospective elementary teachers. The learning skills acquired during the labs were expected to translate into the students' own teaching skills. After each lab, the students were required to analyze the lab's potential use to them as future teachers, while their own learning experiences were still fresh in their minds.

The weekly lab reports were expected to influence learning in the cognitive, behavioral and affective domains. In addition to submitting the answer pages from the lab manual, the students were required to write several sections of the report in their own words. This was in-

tended to foster a deeper understanding of the concepts and learning processes by forcing the student to review their lab work within two days of having done it. Sections in their own writing included the lab's purpose, definition of important terms, the benefits they received as a learner, and the changes they would make in the lab for their potential teaching situations. These were intended to provide some valuable insight and relevance for them as future elementary teachers.

The above aspects of the lab reports were intended to serve primarily as cognitive and behavioral influences on the students. The affective aspects of the students could be influenced by how the instructors grade the lab reports. In this course, certain wrong answers did not severely lower a grade if it was clearly a result of the scientific discovery process. Student perceptions and suggestions were treated with an open mind and with respect. The instructors paid particular attention to the written sections on learner benefits and potential teaching changes. They made positive comments and suggestions when appropriate.

Given an introduction and background to this research, it now seems appropriate to state the Problem Statement and the Research Themes and Questions.

Problem Statement and Research Themes

The purpose of this research is to describe and investigate the effects of a specially designed science content course on the attitudes, knowledge and skills of prospect-

ive elementary teachers toward the learning and teaching of science with the intent that this course could provide an important component for a new teacher training model. The focus of this investigation may be best described in its problem statement:

> What effect does this specially designed physical science class with an emphasis on laboratory activities have on the attitudes, knowledge and skills of prospective elementary teachers regarding the learning and teaching of science?

There are two primary research themes with a number of research questions contained in each theme. The following is a list of both themes with their research questions:

RESEARCH THEME # 1: Describe the nature of the students entering this course in terms of their attitudes, knowledge and skills regarding the learning and teaching of science.

a) What are some of the general educational background characteristics of the students?

b) What are the students' attitudes toward the learning and teaching of science? How can we classify these attitudes?

c) What do the studesnts know about wave phenomena?

d) What science learning skills do the students have? What science learning skills do they value?

e) What science teaching skills do the students perceive as valuable?

RESEARCH THEME # 2: Describe the changes in the students as the result of the instruction experienced in this course.

a) What changes occurred in the students' attitudes toward the learning and teaching of science?

b) What changes occurred in the students' knowledge of wave phenomena?

c) What changes occurred in the students' science learning skills? What changes occurred in their perceived value of science learning skills?

d) What changes occurred in the students' perceived value of science teaching skills?

It will now be interesting to relate some of the introduction and background ideas from Chapter One to some relevant literature in Chapter Two.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The literature review will cover three areas of interest:

1. Literature pertaining to the need for improving science education and science teachers.

2. Review of literature related to developing a new model for training teachers.

3. Literature related to the blending of statistics and ethnography as a unique research approach and its potential in science education research.

The Need for Improving Science Education & Science Teachers

Science educators have perceived the need for improving science education since at least World War II. Several government funding and public awareness efforts have attempted to solve the continuing problem. Over the years, curriculum reform projects have produced mixed results at best. The latest public and governmental outcry started around 1980 when it became apparent that several foreign countries were threatening the economy of the United States. Presently, evidence continues to accumulate regarding the need for better science teaching.

The Spring 1983 issue of Daedalus was devoted entirely to the subject of Scientific Literacy in America. In this issue, Arons makes the following claim about the need to improve science teaching for the survival of our culture:

> If we are survive with our democratic principles and make competent decisions in a competitive world,

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> American citizens need to significantly improve their scientific literacy (Arons, p. 91).

Also in 1983, the National Science Board reported in Educating Americans for the 21st Century on what a student should be able to do after having completed his education. Highlighted are words emphasizing knowledge process skills which are related to the development and use of science learning and teaching skills. These words are short and easily said, but under close examination they can reflect the profound depth of thinking skills involved in their use. The Board states:

> Students who have progressed through the Nation's school systems should be able to use both the knowledge and products of science... in their thinking, their lives, and their work. They should be able to make informed choices regarding their own health and lifestyles based on evidence and reasonable personal preferences, after taking into consideration short- and long-term risks and benefits of different decisions. They should also be prepared to make similarly informed choices in the social and political arenas (NSB Report, p.45).

Progress toward this lofty vision must involve a shift in science educational goals and practices from the current emphasis on a select group of students to an emphasis on preparing all students for a scientific and competitive world. The National Science Foundation's Project Synthesis, Volume 3 edited by Harms and Yager (1981) concerned about this need asked:

> Can science education shift its goals, programs, and practices from the current overwhelming emphasis on academic preparation for science careers for a few students to an emphasis on preparing all students to grapple successfully with science and technology in their own everyday lives, as well as to participate knowledgeably in the important science-related

> decisions our country will have to make in the future? (Harms & Yager, p. 119).

Since 1981, it has become increasingly apparent that science education needs to shift its goals and resources to preparing all of its students.

Part of the needed shift for preparing all students must involve an emphasis on the children's early education. Harms and Yager (1981) also report the observation that young children are naturally curious about the world and are continuously exploring their immediate environment. They state:

> During these early years, they form their basic attitudes, patterns of thought, and modes of behavior. It is, therefore, during these years that particular attention must be given to establishing the attitudes and modes of inquiry that are associated with the scientific enterprise--its processes and content (Harms & Yager, p.73).

If prospective elementary teachers are to teach these attitudes and modes of scientific inquiry to children, then they must have developed these skills in themselves. Overwhelming evidence has indicated that this is not the case. With this lack in development of attitudes, knowledge and skills in prospective and practicing elementary teachers, it should not be surprising that past and present practice shows an overwhelming lack of science emphasis in elementary programs. Poor elementary science teaching has fostered negative attitudes towards science in young students. In Educating Amercians for the 21st Century (1983), the committee extends the Harms' and Yager's observation by making a stronger statement:

> The evidence that students entering primary school exhibit a natural curiosity about... the world around them, but are discouraged from consideration of serious study in these fields early in the elementary grades due to inadequate teaching or lack of motivation (NSB Report, p.42).

As we have seen, the concerns of science educators are beginning to focus on elementary school science. This emphasis in early education is also important for developmental reasons. Benjamin Bloom in Stability and Change in Human Characteristics (1964) describes the importance of introducing the proper attitudes, knowledge and skills to young children with first emphasizing the lack of cultural appreciation of this fact. He states:

> There appears to be an implicit assumption running through the culture that change in behavior and personality can take place at any age or stage of development and that the developments at one age, or stage are no more significant than those which take place at another (Bloom, p.214).
>
> We believe that the early environment is of crucial importance for three reasons. The first is based on the very rapid growth of selected characteristics in the early years and conceives of the variations in the early environment as so important because they shape these characteristics in their most rapid periods of formation... However, another way of viewing the importance of the early environment has to do with the sequential nature of much of human development...A third reason... It is much easier to learn something new than it is to stamp out one set of learned behaviors and replace them by a new set (Bloom, p.215).

Many educators and psychologists do recognize the importance of the proper experiences early in a child's life. However, the common form of teaching in American schools is not encouraging. Atkin in Daedalus (1983) describes some common early science classroom experiences for American children:

> The most common form of teaching in American schools is still the recitation: the teacher asks a question; the child answers it, preferably in the words of the textbook. Typically, the teacher assigns, the children recite, the teacher tests, and then--sometimes-- the class participates in discussion. Further more the questions teachers ask in science frequently focus on definitions and terminology. The essence of the children's task is to search the text for a sentence that contains the correct answer (Atkin, p. 183).

In fact, the more creative and perhaps scientific children, who are willing to think about science rather than just memorize facts, may be actually discouraged from developing their thinking skills. Atkin quotes Stakes and Easley (1978) from Case Studies in Science Education to illustrate this point:

> The student that tries to improvise an answer reveals . . . that he has failed to work thoroughly on the text, and the response is greeted with disapproval (Atkin, p. 183).

Contrary to the prevalent early science experiences, many science educators believe that the elementary classroom should be the place to excite the students' curiosity, build their interest in their world, and practice the methods of science. It should not be a place that is constrained by a textbook. Harms and Yager (1981) in Project Synthesis, Volume 3 describe what they believe and what the "NSF" research believes is the superior elementary classroom:

> Instead the classroom should be the place to excite students' curiosity, build their interest in their world and themselves and provide them with opportunities to practice the methods of science. Such a program can be made conceptually rich by introducing exciting and important phenomena to be observed and

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> analyzed, but it should not reflect a need to cover a syllabus of content in all science disciplines (Harms & Yager, p.75).

This early proper exposure to science is critical to later achievement. Developing many science process skills is not very difficult for most children and should be encouraged. The National Science Board Report, Educating Americans for the 21st Century agrees that an early and stimulating learning atmosphere is the best experience for young science students:

> Early and substantial exposure to ... scientific concepts and processes is critical to later achievement. Early creative and stimulating experience is essential to truly equal opportunity and to effective and continuing study in these fields (NSB Report, p.22).

The Board also emphasizes that these early experiences should involve first-hand experiences in developing science process skills. It states:

> ..., the nature of scientific inquiry and observation presents frequent opportunities for experiencing success with original ideas. Such inquiry does not require unique answers. Students can rightly and successfully report what they have seen and found. This type of experience should be encouraged (NSB Report, p. 44).

The Board realizes and emphasizes the vital role of the teacher in producing the type of early environment for the development of these learning experiences. It states:

> The teacher is the key to education--the vital factor in motivating and maintaining student interest in mathematics, science, and technology (NSB Report, p.27).

Another NSF Report: What are the Needs in Pre-College Science .... Education? significantly concurs with the important influence of the teacher on elementary science. It states:

> The studies found, not surprisingly, that within any classroom the science taught and the way it was taught is dependent primarily on what the individual teacher BELIEVES, KNOWS, and DOES. (My emphasis). Numerous studies indicate that the type of instruction does affect student learning and that the teacher is the most important instructional variable. The critical role of the teacher in instituting changes is well documented (What are ..., p .49).

Too often what the elementary teacher "believes, knows, and does" indicates a very low appreciation of science. According to Harms & Yager (1981), this low appreciation is easily observed in the typical elementary classroom. In Project Synthesis,Volume 3, they state:

> The typical elementary science experience of most students is at best very limited. Most often science is taught at the end of the day, if there is time, by a teacher who has little interest, experience or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will probably come from a textbook selected by a committee of teachers at the school or from teacher-prepared worksheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the student but selected because it is 'in the book' (Harms & Yager, p .73).

One comprehensive explanation for this typically poor elementary science teaching approach is provieded by Harms & Yager (1981). They emphasize the importance of proper teacher training programs, when they state:

> The elementary teacher preservice program has a significant influence on preparing elementary teachers' attitude and knowledge (Harms & Yager, p. 24).

But what kind of influence is the pre-service training, when studies reveal that most practicing elementary teachers exhibit high science anxiety, little knowledge of scie

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science and poorly developed science learning and teaching skills. Project Synthesis, Volume 3 gives the following description of elementary teachers:

> Many elementary teachers lack confidence in their knowledge of science concepts (Harms & Yager, p .88).
>
> Many elementary teachers are not aware or comfortable with different methods of teaching science (Harms & Yager, p .86).
>
> A major reason for the ineffectiveness of many elementary teachers is the lack of proper training in the sciences (Harms & Yager, p. 24).

The NSF Report, What are the Needs in Pre-College Science .... Education? reveals that it is not just the Pre-Service Training Programs that are deficient, but there is a SIGNIFICANT LACK OF SUPPORT SYSTEMS for science education as a whole and the public at large:

> ...it is apparent that an alarming number of adults cannot tell sense from nonsense (What are ..., p. 97).
>
> The whole climate under which teachers are working is less favorable to the pursuit of excellence than it was in the latter part of the 1950's and most of the 1960s (What are ..., p. 96).

The above indicate that the general public is not able or willing to give the needed support for improving science education. The following excerpts show that a lack of insight and expertise exists within most school systems in the nation. This NSF report continues:

> Science and the development of critical thinking skills ....have assumed a low priority in the thinking of school administrators. An increased emphasis on the "basic" learning skills such as reading, arithmetic, and spelling, is pre-empting time previously available for the study of science...especially in elementary schools... and were seen as having a rather

> limited value for the student body at large... (What are ..., p. 96).
>
> Few school principals have a good academic background in science... this make it difficult for them to help teachers to develop effective science... instructional programs (What are ..., p. 97).

From the above, it seems that unfortunately, there are not as many opportunities as there once were for teachers to improve their knowledge of science and their science teaching skills. In spite of this frustration, prospective and practicing desire better pre-service and in-service science education programs. The above NSF report says:

> Large number of teachers have said they wanted greater opportunities to learn new teaching methods, especially regarding the use of 'hands-on' materials and the implementation of the discovery approach (What are ..., p. 100).

This frustration of teachers' expectations for themselves has some possible implications for their expectations of their students as learners, according to Lezotte, Hathaway, Miller, Passalacqua, & Brookover (1980) in their School Learning Climate and Student Achievement:

> Teachers' expectations for students are closely tied to the expectations teachers hold for themselves. It is essential for teachers to have high expectations for themselves as teachers and high expectations for students as learners (Lezotte et al., p. 103).

Although the influence of expectations on the elementary students is important, the greater significance may be the origin of low expectations starting with the university staff has for their prospective and practicing elementary teachers. According to Lezotte, et al., the level of expectations can have a significant effect on the level of

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achievement the elementary teachers exhibit in developing their own science learning and teaching skill during their university teacher training programs. They profess:

> This involves the self-fulfilling prophecy in which expectations of achievement are communicated by the teacher through both overt and subtle means. The student then conforms to the level of expectation rather than to his or her actual level of ability. The teacher, in turn, perceives this performance level as the actual ability level, which confirms the original judgment (Lezotte et al., p. 52).

The above samples of literature have given some insight into several major problems concerning the improvement of science education and the training of science teachers. These quotes contain some of the criteria for a new teacher training model by focusing some attention on the need to improve the attitudes, knowledge and skills of prospective and practicing elementary teachers. The next area of focus will be the review of some literature related to developing a new model for training teachers.

Some Criteria for Developing a New Teacher Training Model

The separation of human life into 3 learning domains is only one model of life and therefore somewhat artificial and limited. Life does not exist separately in 3 domains. However, Bloom et al., created a 3 domains model as a tool for analyzing human learning processes. The previous section has strongly suggested that the 3 domain framework is appropriate for this analysis. It also suggested that to improve science teaching, one must structure a teacher training model which improves effectively and efficiently the attitudes, knowledge and skills of prospective and practicing elementary teachers. Based on present analysis the effectiveness of past training programs is questionable. The number of required courses in elementary education suggests that few new courses can be added to the program and that efficiently using the present number of courses is important.

The intimate interactions of the affective, cognitive and behavioral domains and the desire for effectiveness and efficiency in teacher training programs suggests that specially designed courses are needed. These courses would be designed to influence simultaneously the students'attitudes, knowledge and skills regarding the learning and teaching of science. The idea of their intimate interactions is not new, but little, if anything, has been done to try to implement this special type of course into a teacher training program. Some psychological references to this type of model deserve examination.

Some psychologists have formed models that treat the affective, cognitive, and behavioral domains as being very closely related. Rokeach (1968) uses such a model in describing belief systems in _Beliefs, Attitudes, & Values:_

> Each belief ... is conceived to have three components: a _cognitive_ component, because it represents a person's knowledge, held with varying degrees of certitude ...; an _affective_ component, because under suitable conditions the belief is capable of arousing affect of varying intensity ... and a _behavior_ component, because the belief, being

> a response predisposition of varying threshold, must lead to some action when it is suitably activated. The kind of action it leads to is dictated strictly by the content of the belief (Rokeach, pp. 113-114). (my emphasis)

> It is not enough merely to assert that social behavior is a function of two attitudes. To predict behavioral outcome requires a model about the manner in which two attitudes will cognitively interact with one another (Rokeach p. 136). (my emphasis)

The ideas in the above excerpts were expressed consistently in the previous literature section. The teaching process is a complex social behavior greatly influenced by the instructor's attitudes and knowledge. One quote that expresses this belief is worth repeating in part. The NSF Report states:

> The studies found, not surprisingly, that within any classroom the science taught and the way it was taught is dependent primarily on what the individual teacher BELIEVES, KNOWS, and DOES (What are ..., p. 49) (My emphasis)

Changing human beliefs is never a simple process and becomes even more difficult in later life. Changing the attitudes, knowledge and skills of prospective teachers regarding the learning and teaching of science is no exception. Bloom (1964) in Stability and Change in Human Characteristics points out the great effort and attention necessary to change some characteristic later in life:

> ... to produce a given amount of change (an elusive concept) requires more and more powerful environments and increased amounts of effort and attention as the characteristic becomes stabilized. In addition, the individual not only becomes more resistant to change as the characteristic becomes stabilized but change, if it can be produced, must be made at greater emotional cost to the individual... it is less difficult for the individual and society to bring about a particular type of development early in the

history of an individual than it is at a later point in his history (Bloom, p. 230).

Bloom, as well as others, have emphasized the importance of culturing the proper experiences early in one's life for developing scientifically literate citizens. The above helps to reinforce the importance of a model that treats elementary teachers who greatly influence young children. It also reinforces the early science training of elementary teachers as in a pre-service program as opposed to an in-service program.

Atkin reinforces the importance of elementary science teaching in Daedalus (1983):

> By focusing more of the available science teaching talent on elementary schoolchildren, science interest would be heightened among a broader group of the population than is now the case, and those who do not choose to move into science related careers would have a general background sufficient to raise science knowledge in the population significantly (Atkin, pp. 184-5).

Ball-Rokeach, Rokeach & Grube in The Great American Values Test give numerous ideas for initiating the process of producing stable changes in individuals:

> Processes of both stability and change may be initiated in persons if information contains the following characteristics: 1) appeals to the curiosity. 2) is potentially useful. 3) does not require too much specialized training or effort to understand. 4) appears credible and intuitively correct. 5) within the repertoire of the person to act upon the information, either to alleviate dissatisfaction or enhance satisfaction. Satisfaction reinforces competence and dissatisfaction becomes an impetus for change. 6) The information is presented under conditions that minimize ego defense (Ball-Rokeach, p. 36).

Hands-on experiences in the physical sciences can fulfill much of the above criteria and be tested as a working model. However, the lack of hands-on experiences and proper science courses lead the National Science Board in Educating Americans for the 21st Century suggests:

> that our students (prospective teachers) spend too little time in the course of their schooling in the study of academic subjects ... and devote too little time to 'hands-on' experiences (NSB Report, p. 23).
>
> Elementary... science teachers should be required to have ...college courses in ... the physical sciences (NSB Report, p. 32).

Some of the benefits of hands-on laboratory experience have been studied. The NSF Report: What are the Needs in Pre-College Science..Education? list five benefits of the laboratory-inquiry approach that would be appropriate for teaching prospective elementary teachers. A simplified listing from page 95 is:

1) Lab work provides personal experiences for students.
2) Lab experiences provide information that is almost impossible to convey in a textbook.
3) The lab requires activity of students in a time when young people lead increasingly passive lives.
4) Scientific observations and experiments frequently show limitations and uncertainties of scientific procedures.
5. Most students find that lab work is fun.

In order to produce change in prospective elementary teachers, another area to be included in a good model is promoting constant vigilance on the part of the instructors to make certain that their intentions for the class are clearly communicated. Lezotte, et al., in School Learning Climate & Student Achievement point out:

> ...the fact that the messages teachers intend to communicate and the messages the students actually perceive may be quite different. No matter how well-intended the message, its real effect is grounded in the student's perception of the message (Lezotte, et al., p. 103).

The literature review for this and the previous section has provided a criteria for an effective teacher training model. The prominent features in this criteria include the following:

1) Elementary teacher training programs must be held responsible for some of the existing problems in in elementary science education. The existing programs need to design new courses to address these problems.

2) The problems found in elementary science education fit well into the categories of attitudes, knowledge and skills. Courses must be developed that influence all 3 categories.

3) Based on some psychological learning principles and the large number of courses in present programs, the most effective and efficient approach for producing the changes in all 3 categories may be to design a course that influences all 3 categories simultaneously.

4) This specially designed course must include in its planning some knowledge about psychological learning theories that involve changing human attitudes, knowledge and skills. Theories that involve the difficulty of changing human characteristics in children and adults must be considered.

5) This special science course needs to include hands-on laboratory expereinces that are presented in an environment that minimizes anxiety and increase curiosity. The students, according to some learning theory, will need to experience an instructor who a role model for the attitudes, knowledge and skills that are to be developed in the prospective teachers.

This specially-designed physical science course appeared to contain much of the above criteria in its design and could provide a model of this criteria for investigation.

For example, it has the treatment of the three domains of Attitudes, Knowledge and Skills as equal objectives, provides hands-on experiences, and involves constant instructor vigilance for student feedback. Be that as it may, the primary focus of this research is to describe this specially-designed class and identify its benefits. If the class has some merits and if it fits some of the criteria for a testable working model for improving science teaching, then these issues will be discussed in the following chapters.

Generally, the above literature review criteria indicated the need for improving the attitudes, knowledge, and skills of prospective elementary teachers regarding the learning and teaching of science if the future American social and economic needs are to be fulfilled. It also advocated new models for teacher training programs in order to encourage these needed changes effectively.

In Chapter 1, an extensive discussion involving the need for blending research approaches was given along with important citations. Since, a blend of statistics and ethnography was used as the research approach for describing this class and evaluating its benefits, a short literature review of the need for this blend now follows.

The Need for a Blend of Approaches

An accurate investigation of complex learning situations require research approaches that have few weaknesses.

One way to deal with this type of problem is to blend several approaches so that they minimize each others weaknesses. Since the experimental-quantitative and the ethnographic-qualitative approaches to research have their strengths and weaknesses, this research, hopes to maximize their strengths and minimize their weaknesses. Experimental-quantitative research has been successful in defining problems, making hypotheses, controlling variables, and making predictions within certain specified limits. However, this approach tends to foster reductionism and often creates difficulties of applying its conclusions to the real world of education.

Statistical surveys and questionnaires were used in this research to investigate the attitudes, knowledge and skills that the students had upon entering this course and to measure some the changes in these characteristics that the students may have experienced during this course. However, the statistics did not tell us what the students were thinking, what unmeasured characteristics may have changed, what parameters may have caused the change, how long the changes might last, what the scope of the changes might be, and numerous other qualitites that cannot be reduced to numbers. Ethnographics methods were essential for a deeper understanding the features in this complex environment.

Gallagher (1985) in his "Qualitative Methods for the Study of Schooling" indicates some of the strengths of the ethnographic-qualitative approach:

> Ethnography ... is a naturalistic approach to research which is holistic and not limited by reductionism. Ethnographers study people as they are; we do not conduct controlled experiments. We shun predefinitions. We emphasize understanding of reality as seen by those who are studied, and we do not strive for predictions (Gallagher p. 3).

He later gives some examples of the type of questions ethnographers ask:

> My questions are like the following: What are teachers' and students' perspectives, values, and understanding of their reality? What gives them joy and stress, satisfaction and worry (Gallagher, p. 6).

Some of the problems with the ethnographic-qualitative approach is that the results are usually based on small numbers of individuals thus raising serious concerns about generalizations from the results, that the concepts of reliability and validity do not apply in the same way as they apply in the experimental-quantitative approach, and that a lengthy period of data collection complemented with triangulation is necessary for reducing observer subjectivity.

In this blend, all the various aspects of both approaches will not be utilized. The strengths selected from each approach will be discussed in the next chapter. However, a brief description of interviewing and triangulation at this point may help clarify the need for a blend.

Gorden (1980) in his book, <u>Interviewing: Strategy, Technique and Tactics</u> delineates the value of interviews and the need for triangulation:

> Interviewing is most valuable when you are interested in knowing people's beliefs, attitudes, values, knowledge, or any other subjective orientation or mental

> content.... The exploratory values of the unstructured interview are impossible to attain in a questionnaire where there is no opportunity to formulate new questions or probe for clarifications (Gorden, p. 11).

> ...use multiple methods whenever possible. This use of multiple methods, each to cross-check or supplement the others, is often referred to as triangulation....Often the nature of the problem under investigation demands a multi-method approach because the various methods give totally different kinds of information that can supplement each other ... or because we need a cross-check to verify the validity of our observations (Gorden, p. 12).

This blend of research approaches with citations was discussed in Chapter 1 and will be further discussed in the subsequent chapters. The reader is referred to these discussions if further knowledge is needed for understanding the need for a blend of research approaches.

A general summary for Chapter 2 now seems appropriate. The need for improving science teaching ranges from personal to national needs. The importance of early learning experiences emphasizes the need for improving elementary "science" teachers. Since many elementary and prospective elementary teachers lack the proper attitudes, knowledge and skills regarding science and science teaching, a model for improving all three domains is needed. Available evidence resulted in the authors speculation that a most effective and efficient model would deal with all three domains simultaneously. In addition, a research design blending the experimental and ethnographic approaches seems the most appropriate for investigating a given class related to such a model.

CHAPTER THREE

RESEARCH DESIGN AND DATA

This study was designed to address a broad research question:

> What effect does this specially-designed physical science class with an emphasis on laboratory activities have on the attitudes, knowledge, and skills of prospective elementary teachers regarding the learning and teaching of science?

In reference to the problem statement, the following major research themes were given with their related research questions.

1) Describe the nature of the students entering this course in terms of their attitudes, knowledge, and skills toward the learning and teaching of science.

    a) What are some of the general educational background characteristics of the students?

    b) What are the students' attitudes toward the learning and teaching of science? How can we classify these attitudes?

    c) What do the students know about wave phenomena?

    d) What science learning skills do the students have? What science learning skills do they value?

    e) What science teaching skills do the students perceive as valuable?

2) Describe the changes in the students as the result of the instruction experienced in this course.

    a) What changes occurred in the students' attitudes toward the learning and teaching of science?

b) What changes occurred in the students' knowledge of wave phenomena?

c) What changes occurred in the students' science learning skills? What changes occurred in their perceived value of science learning skills?

d) What changes occurred in the students' perceived value of science teaching skills?

Before describing this study's research design and data, several specific points of the course description from chapter 1 will be restated for the reader's benefit.

The staff's intentions were to improve the scientific attitude, knowledge and skills of prospective elementary teachers in a science content course. Traditionally, science content courses for elementary teachers have attempted to improve primarily the science knowledge of prospective elementary teachers. The intention in this course was to treat each area--attitudes, knowledge, and skills--as an equally important objective for improving the science teaching competency of prospective elementary teachers. However, putting greater emphasis on reducing science anxiety immediately for the students would be attempted as part of the course design.

This attempt by the staff was addressed by trying to create a "non-threatening" environment as perceived by the students. The design for this "non-threatening" science content course included the following:

1) An easy-to-read textbook with no sophisticated mathematics but good diagrams and applications.

2) A lecture format with many demonstrations that were related closely to the textbook readings.

3) Many hands-on laboratory activities related closely to the concepts discussed in the lectures and textbooks.

4) Other pedagogical designs which included:

   a) structured review sessions.
   b) the opportunity for the students to ask many questions of the laboratory instructor without fear of ridicule or punishment.
   c) discussion of ideas with their peers.
   d) instructor openness to student feedback.

Although greater emphasis was on reducing science anxiety immediately, the staff believed that stabilizing lower student anxiety could only be accomplished by the students successfully acquiring "real" science content and science learning skills. Science content not only meant that the students retained correct information about some science concepts but that they would acquire a higher level of understanding that would translate into practical applications for the student. Science learning skills would be developed by hands-on, guided discovery experiences not fill-in-the-blank questions from pseudo-lab books. The science learning skills should become an active part of the students' higher thinking skills used throughout the course of their lives. In this study, the science content and learning skills would be developed by primarily the understanding of wave phenomena in general and then in terms of sound and light.

Consistently underlying the course design is the staff's belief that attitudes, knowledge and skills are interrelated and mutually influencing each other. Their artifical separation is a convenient approach for concept-

ualizing them so that research and communication may be done in a less confusing manner, but in a real individual their relationships exist in a non-linear pattern. In addition to the preceding paragraph's description of this interrelationship, the staff believed the course design would help the students increase the number of learning skills and teaching skills that they would perceive as useful for themselves and their future elementary students.

RESEARCH DESIGN

In describing the research design, references will be made to research ideas mentioned in previous chapters. Both experimental and ethnographic techniques were used to describe the nature of the students entering the course and were used to describe the changes in the students as a result of the course instruction. The use of both techniques could increase the accurancy of the needed description of the course effects by supplying both statistical and subjective data. They could also be used to counteract some anticipated criticism of certain aspects of the research design. Each approach could not only complement the others' description, but act as a guide for checking for consistence with each others' data. This should be clear after the following discussion.

This section will first describe how some anticipated criticisms were considered in the research design. Secondly, it will list and then descirbe in some detail the types of instruments used in the data collection. Finally, it will give the schedule of how the data was collected and then describe the data.

The author had two major concerns with his research design which he also anticipated as being justifiable potential criticism of this study. They are: 1) A concern for the objectivity of some research data, because the author taught one of the laboratory sections in this course. 2) The potential criticism that the course reduced student anxiety toward science but the students did not increase their knowledge of science. Part of the complexity in the research design with its number of research instruments was created in the attempt to successfully address the above concerns.

The concern for objectivity was addressed directly in the research design in at least two ways: 1) Data would be collected from all sections of the course, not just the author's section with student responses related to all aspects of the course. 2) The identifiable student responses would be checked for general consistency with anonymous responses. The concern for gaining knowledge in a science content course was addressed not only by the regular course assessment but addressed also by the research design's pretest and posttest knowledge questionnaires. Other research design concerns will be discussed later.

Two types of research approaches were used in this study. The Experimental approach involved research instruments which produce quantitative, statistical data. The

Ethnographic approach involved methods produce qualitative, descriptive data. Both approaches would be used in a pat-pattern that would verify, refute and complement each others' data. They are listed below along with the appendix in which a copy of the "instrument" involved in each approach can be found with a summary of the data related to each. A detailed instrument or method description follows this list.

EXPERIMENTAL INSTRUMENTS: (Appendix E)

1) Surveys: a) background, b) attitudes and c) skills.

2) Knowledge Questionnaires: a) definitions, b) sketches and c) explanations.

ETHNOGRAPHIC METHODS:

1) Special Research Exercise: (Appendix A) a) influence on knowledge, b) influence on attitudes, c) influence on learning/teaching skills and d) comparison between laboratory and other learning experiences.

2) Interviews: (Appendix B) Questions related to a) attitudes, b) knowledge, c) learning/teaching skills and d) course benefits.

3) "Transfer" of Learning/Teaching Skills (Appendix C) a) influence of learning environment on students, b) influence of teaching strategies on students.

4) Anonymous Student Evaluation: (Appendix D) General evaluation of course including instructors.

5) Wave Laboratory Description: a) written documents (Appendix E) b) outside observers' field notes, c) videotape and d) audio tape.

<u>Description of Experimental Instruments and Ethnographic Methods: Their Use, Timing and Data Table References:</u>

<u>Background-Attitudes-Skills Surveys</u>

A background survey as part of a larger background-attitude-skills survey (Appendix E) was given on the first day of the class. Students' information on their major, college year, past science and educational experiences, and expectations for this class and their future careers are examples of data requested. Table 1 appears in Appendix F and lists pertinent data from this survey, which will be discussed later in this chapter.

ATTITUDES

Two science attitudes surveys were conducted. The first attitude survey was constructed by the author as a low inference survey and is part of the background-attitude-skills survey (Appendix E). There were 8 questions related to science attitudes. These were straight-forward questions rather than implied questions. The questions were asked directly, for example: "My anxiety toward learning science is . . ." A 5-point response scale was used and for this example 1 = highest anxiety and 5 = lowest anxiety. The author's survey was given on the same day as the SAI and the students had 15 minutes to respond to it. The author used this survey, not only because of questions about the SAI's validity, but because it clearly addressed with low infer- ence some issues that the SAI did not clearly address, if it addressed them at all. Table 2 appears in Appendix F.

The second survey is the Moore & Sutman (1970) Scientific Attitude Inventory (SAI). See Appendix E for a coded copy. The SAI has been very popular and was used even though the author and other writers (Munby 1983) have some questions about its validity and the appropriateness of its questions. This will be discussed later in Chapter 4 in the Reliability and Validity section. The SAI is a 60-item Likert-type instrument with a 4-point response scale ranging from strongly agreeing with a statement to strongly disagreeing with a statement (there is no neutral response).

The concept "scientific attitudes" is meant by the SAI's authors to represent those habits of the mind generally associated with critical thinking and typically taken to characterize the mental processes of scientists at work. It is evident to some of the SAI's critics, however, that the conception of attitude towards science in this survey goes further than the notions of critical and "scientific" thinking. This point will be discussed later in Chapter Four.

The SAI has 6 subscales which are divided into a "positive" and "negative" aspect. For example, Subscale 1A: "Scientific Laws/Theories are approximations of the Truth ans subject to change." is the "positive" attitude while Subscale 1B: "Scientific Laws/Theories are Unchanged Truths." is the "negative" attitude. The other subscales are given in Table 3. Each subscale has ten statements which, for scoring are evenly distributed into positive and negative. The SAI was given the second day of each class and during the last week of each class. The students were given about 15 minutes each time to indicate their responses. A copy of the SAI is given in Appendix E. Table 3 appears in Appendix F.

SKILLS

A learning and teaching skills survey was also conducted as part of the background-attitude-skills survey (Appendix E) given at the beginning of the course and then repeated at the end of the course. The students were asked to rate different learning and teaching activities on a 5-point scale ranging from "not helpful" to "extremely helpful". Table 9 appears in Appendix F.

Knowledge Questionnaires

Several types of questionnaires were used to describe and assess the students' knowledge of scientific concepts. The first questionnaires used on the first day of class tried to evaluate the students' understanding of wave phenomena upon entry into this course.

Wave phenomena was chosen for several reasons:

1) The concept was introduced at the beginning of the course and posttests would be easier to do.

2) The concept related to most of the phenomena studied in the course and is used by the staff as a means for connecting seemingly diverse phenomena such as sound and light on a subtler level of understanding.

3) Very little, if any, research has been done on understanding the concept.

There were two types of questionnaires on wave knowledge. One type asked for specific answers to definitions, sketches, and situations. The other asked open-ended questions based on the students' experiences. Both types had their responses coded. Their results, post-test and "delayed" post-test timing will be discussed later. Intercoder reliability will be discussed in Chapter 4. Copies of each questionnaire are included in Appendix E.

Special Research Exercise and Transfer of Learning/Teaching Skills Exercise

After the Sound and Light units in the course, the students were given an open-ended Special Research Exercise (Appendix A) to take home. It was due the following week. Here, in their own words and from their own perception, they were asked to reflect on how the lab had helped them understand waves & sound and light & color. They were also to comment on how the laboratory had influenced their attitudes and learning skills, and how the lab compared to other aspects of the course. This descriptive exercise provided an insight into the students' perception of the course and its benefits.

Just before the last week of each class (Spring & Summer), the students were given another open-ended research exercise to take home. This was called "Transfer of Learning/Teaching Skills" (Appendix C) and was due by the last day of class. Again, in their own words and from their own perception, they were to summarize their knowledge of waves, but in addition they were to reflect on how their lab experience may have influenced their learning and teaching "skills".

An aid in helping the students with both lab open-ended exercises was their lab reports. After each lab, they were required to write in their own words the lab's purpose, content, and benefits. However, the most significant question requested (while the lab experience was still fresh in their minds) was their ideas for changing the lab to meet their own potential teaching situation. Copies of part of the students' wave labs were kept by the author for reference. A copy of the wave lab itself is in Appendix E.

Interviews

During the Spring term, interviews were given from the fifth week to about the ninth week of the term. In the Summer term, interviews were given from the fourth through the fifth week of the half-term. Students were selected for interviews primarily on the basis of their indication of high science anxiety on the author's attitude survey given the first day of class. The interviews focused on gaining greater insight into the students'attitudes, knowledge, and skills regarding science and science teachings. The interview questions were guided to a great degree by the students' responses from previous research instruments and course materials. The interviewer reviewed the student's materials before each interview and could refer to them during the interview. The interview format used also allowed the asking of probing questions based on the student's interview responses. These interviews were an important source of insight into the character of the students' science anxieties and their perception of the course and its benefits.

Anonymous Student Evaluation

At the end of the course, the university requires that the students have an opportunity to fill out an anonymous course evaluation. The instructors encouraged the students to write comments about the course on the back of the form. Being anonymous, the students' responses could be compared with other resposnes containing students' names and could give some hints about the reliability and validity of the research instruments.

Wave Laboratory Description

There were three lab sections during Spring term. Two outside observers took field notes during one section's wave lab. A videotape was made during another section's wave lab and an audio tape was made of the third section's wave lab. These were done to monitor the lab treatment for its consistency of teaching approach for the wave knowledge research and, if appropriate, serve as aids to triangulation with the primary ethnographic instruments. A copy of the Wave Lab is in Appendix E.

LIST OF RESEARCH INSTRUMENTS ACCORDING TO RESEARCH THEMES

In summary, here is a list of the previously described research instruments arranged so that it becomes clearer which major research theme they address. The list includes when the instruments were administered:

Research Theme # 1:

Describe the nature of the students entering this course in terms of their attitudes, knowledge, and skills regarding science and science teaching.

a) Background Survey: first day of class
b) Author's Attitudes & Skills Survey: first day
c) Moore & Sutman's SAI: first & second day
d) Wave Knowledge Questionnaires: first & second day of class
e) Interviews: started after Sound & Light units but would contain some entry level data.
f) Special Research Exercise: after Sound & Light units but would contain some entry level data.
g) Transfer of Learning/Teaching Skills: last week of class but would contain some entry level data.

Research Theme # 2:

Describe the changes in the students as the result of the instruction experienced in this course.

a) Author's Attitudes & Skills Survey: last day of regular class before final examination week.
b) Moore & Sutman's SAI: last day of regular class before final examination week.
c) Wave Knowledge Questionnaires: after Sound & Light units and the last week of regular class.
d) Interviews: started after Sound & Light units and continued to end of course.
e) Special Research Exercise: after Sound & Light unit & taken home for several days to answer.
f) Transfer of Learning/Teaching Skills: last week of class & taken home to answer.
g) Anonymous Student Quotes from university required course evaluation form: last day of class

As can be seen, both research themes are addressed by multiple data sources for comparing results. The research design can be further clarified by arranging the above instruments in a time schedule of dates showing when they were used during Spring term 1985.

Schedule of Data Collection

Data were collected according to a set schedule each term. Here is an example of the schedule used for Spring Term 1985 given in outline form:

27-28 March: Pretests: Knowledge of "Waves" questions
Author's Background-Attitude-Skills survey
Moore & Sutman SAI survey

9 April: Lab Treatment: Primary Waves Lab experience
Sec. 1: Outside Observers
Sec. 2: audio tape
Sec. 3: videotape

24-25 April: Posttests: Knowledge of "Waves" questions

26-29 April: Ethnographic: open-ended lab questionnaires asking: How lab helped in understanding waves, etc.? How lab influenced attitudes and skills? How lab compares to other learning experiences?

1-8 May: Interviews: Questions related to Attitudes, Knowledge, and Learning/Teaching Skills. Lab & Lecture Benefits?

23-31 May: Interviews: Questions about Attitudes, Knowledge, & Learning/Teaching Skills. Lab & Lecture Benefits?

29 May - 7 June: Posttests: Knowledge of "Waves" questions, Author's Attitude-Skills survey, Moore & Sutman SAI survey.

29 May - 7 June: Ethnographic: open-ended lab questionnaires asking: Summarize & transfer Knowledge about Waves. Relate lab experience to Learning/Teaching Skills.

7 June: Ethnographic: anonymous student course evaluation

The Summer term schedule was in the same sequence but condensed to fit into 5 weeks. In addition, there was only one set of interviews and only one posttest on wave knowledge. We will now look at some of the data collected.

Data & Data Tables

BACKGROUND SURVEY (n = 54)

The data for Table 1 came entirely from background section of the author's background-attitudes-skills survey. The whole survey was actually given twice each term. It was expected that the background information would not change and the attitudes and skills would change. The consistency of the background material would be a preliminary reliability for the expected change in the attitudes-skills ages remained relatively the same, while there were significant changes in the attitudes-skills shown on different tables. The slight change in background percentages is easily explained by the difference in the sample size. Although the sample size during the Summer term remained the same, the Spring sample size decreased by 4 between the first day of class and the last week of class. This resulted in the total sample size decreasing from 58 to 54 students. The data in Table 1 are based on n = 54.

Under major (Q-1), the 5.6% "other" was found to be individuals leaning toward elementary education, but had not decided yet. This class is intended for sophomores in their teacher training programs, but (Q-2) Seniors and Juniors make up the large majority (87%) of the class. The 3.7% Special Students were people working for teacher certification after having earned a bachelor's degree.

Only one-third of the students (Q-14) had much of what they considered "activity" experiences in their elementary

TABLE 1 : GENERAL STUDENT BACKGROUND (n = 54)

STUDENT-QUESTIONNAIRE RESPONSES ARE GIVEN IN PERCENTAGES.

Q-1: MAJOR? 88.9 Elementary Education
5.6 Special Education 5.6 Other

Q-2: CLASS? 57.4 Seniors 29.6 Juniors
9.3 Sophomores 3.7 Special Student

Q-14: CLASSIFY YOUR ELEMENTARY SCIENCE ACTIVITY.

33.3 Much Activity 51.9 Little Science Activity
14.8 Little or No Science

Q-15: WHY DID YOU ENROLL IN THIS CLASS?

72.2 A Major or College Requirement
25.9 A Requirement, but also wanted to
1.9 No Requirement, but wanted to

Q-18: OVERALL GRADE POINT AVERAGE

3.5-4.00:	14.8	2.5-2.99:	37.0
3.0-3.49:	35.2	2.0-2.49:	13.0

Q-36: 40.4% of PHS 203 students had their Science Methods Course with the following influences:

Q-37: DEGREE TO WHICH SCIENCE METHODS CLASS WAS ENJOYED

low	2	3	4	high
15.4	11.5	23.1	30.8	19.2

Q-38: DEGREE OF SCIENCE-TEACHING COMPETENCE FELT AFTER SCIENCE METHODS CLASS

low	2	3	4	high
4.8	28.6	28.6	28.6	9.4

Q-39 & 40: 20 % of the students had completed STUDENT TEACHING in which 23.1% taught science in K-3 & 76.9% in 4-6

Q-41: DEGREE OF SCIENCE-TEACHING COMPETENCE FELT AFTER STUDENT TEACHING EXPERIENCE

	LOW	2	3	4	HIGH
pretest	7.7	0.0	15.4	46.2	30.8
posttest	14.3	14.3	7.1	57.1	7.1

education science classes. Almost three-fourths (72.2%) of the student (Q-15) were forced to take this class through some type of degree requirement. The distribution of overall grade-point average (Q-18) does not seem out of the ordinary.

This class (PHS 203) is intended to help students with their science methods class, but 40.4% of the students (Q-36) had already taken it. The relative attitudes of those who had taken methods are given in the next two scales (Q-37 & Q-38). An interesting side point comes from an instructor who has taught both this class and methods classes. He has said that those students who have taken PHS 203 before his methods course "generally do much better in methods than those who had not taken 203."

In addition to already having taken methods, 20% of the students (Q-39 & Q-40) had done their student teaching. All of them said they had taught some "science". However, their perception of the degree of competence they felt about the science teaching they <u>had done during</u> their student teaching (Q-41) DECREASED after having experienced this class. This interesting point will be discussed later in Chapter 4.

AUTHOR'S ATTITUDE SURVEY (n = 54)

The data for <u>Table 2</u> were created totally from the attitude questions on the author's background-attitude-skills survey given to both terms' students (n = 54). A brief description of each item will be given.

Looking at Table 2, it can be seen that for (Q-30) course difficulty 70.4% of the students anticipated high difficulty and 35.2% after the course thought it had been so. For course interest (Q-31), 63% of the students anticipated high interest and afterwards 81.5% thought it had been so, with all of the increase occurring in the highest interest category.

As expected, most students perceived the questions on science enjoyment (Q-32) and science attitude (Q-33) to be similar, thus showing some consistency. Based on their past science courses, about one-third of the students for both categories indicated fairly high enjoyment of science. After this class, their rating for both questions jumped to 77.8% for the same grouping (4 & 5 level of response).

Although science anxiety (Q-34) was high, physics anxiety (Q-35) was even higher for a number of students. Before this course, 51.9% of the students had high to very high science anxiety and 68.5% were in the same group for physics anxiety. After this course, only 11.1% were in the high range and very high science anxiety had dropped for 28.8 % to 0 % of the students. For physics anxiety, the two higher anxiety reponses dropped 55.5% to 13% , while the very highest dropped from 37% to 1.9% of the students.

Q-49 and Q-50 are related but not exactly the same. Most of the students had anticipated a fairly high enjoyment with teaching science to children but a large increase does take place in the highest level where it increases

TABLE 2: ATTITUDES TOWARD LEARNING & TEACHING SCIENCE
(n = 54)

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: GENERALLY 1-5 = MOST NEGATIVE TO MOST POSITIVE
REFER TO EACH QUESTION FOR PARAMETERS

	1	2	3	4	5
Q-30: COURSE DIFFICULTY	VERY DIFFICULT				VERY EASY
pretest	20.4	50.0	25.9	3.7	0.0
posttest	5.6	29.6	37.0	22.2	5.6
Q-31:COURSE INTEREST	VERY BORING				VERY INTERESTING
pretest	1.9	0.0	35.2	42.6	20.4
posttest	1.9	1.9	14.8	42.6	38.9
Q-32: SCIENCE ENJOYMENT	VERY LOW				VERY HIGH
pretest	16.7	16.7	33.3	16.7	16.7
posttest	1.9	7.4	13.0	46.3	31.5
Q-33: SCIENCE ATTITUDE	DON'T LIKE				LIKE VERY MUCH
pretest	13.0	16.7	40.7	16.7	13.0
posttest	1.9	7.4	13.0	53.7	24.1
Q-34: SCIENCE ANXIETY	VERY HIGH				VERY LOW
pretest	27.8	24.1	24.1	16.7	7.4
posttest	0.0	11.1	29.6	38.9	20.4
Q-35: PHYSICS ANXIETY	VERY HIGH				VERY LOW
pretest	37.0	31.5	16.7	13.0	1.9
posttest	1.9	11.1	16.6	59.3	11.1

Q-49: ANTICIPATED ENJOYMENT OF TEACHING SCIENCE TO CHILDREN

	VERY LITTLE				VERY MUCH
pretest	0.0	5.9	21.6	51.0	21.6
posttest	0.0	5.9	11.2	45.1	37.3

Q-50: ANTICIPATED % OF TIME DEVOTED TO TEACHING SCIENCE

	<5%	5-10%	10-15%	15-20%	>20%
pretest	0.0	17.6	35.3	27.5	19.6
posttest	0.0	6.0	28.0	44.0	22.0

Q-39: STUDENTS WHO HAVE DONE STUDENT TEACHING WERE 20%
Q-40: OF THESE, 23.1% TAUGHT SCIENCE IN K-3 & 76.9% IN 4-6
Q-41: DEGREE OF COMPETENCE FELT AFTER TEACHING SCIENCE.

	LOW	2	3	4	HIGH
pretest	7.7	0.0	15.4	46.2	30.8
posttest	14.3	14.3	7.1	57.1	7.1

from 21.6% to 37.3% of the students comparing before and after this course results. The anticipated percentage of time devoted to teaching science makes a significant increase if we look at the above 15% groups. On the pretest, 47.1% of the students wanted to devote more than 15% of their time to science and on the posttest 66% did.

The degree of competence felt after teaching science during student teaching has already been mentioned in Table 1 and will be interpreted in the next chapter. The significance of this data will be discussed and interpreted in Chapter 4.

MOORE & SUTMAN SCIENTIFIC ATTITUDE INVENTORY (SAI) n = 54

Results from the Moore & Sutman SAI survey are given in Table 3. The SAI is a 60-item Likert-type (1932) instrument with a 4-point scale (there is no neutral response) ranging from "strongly agreeing" with an item to "strongly disagreeing" with an item. The Likert scale is based on a number of items having a characteristic that the more favorable the subjects' attitude toward a given object, the higher the expected score for the item.

In the SAI, scale construction involves 10 items related to each attitude object. In Table 2, the numbers 1 through 6 in front of the letters A or B are the six attitude objects. According to Likert and the SAI, one-half of the ten items (the "A's" after the numbers 1 - 6) are designed so that "agree" would represent a favorable response, while selecting "disagree" in the remaining one-

TABLE 3: MOORE & SUTMAN SCIENTIFIC ATTITUDE INVENTORY
(n = 54)

Mean Differences between pretests & postests are shown for each subscale.

1A. SCIENTIFIC LAWS/THEORIES ARE APPROXIMATIONS OF THE TRUTH AND SUBJECT TO CHANGE.

pretest	10.2105	shift -.1930
posttest	10.4035	increases 1a attitude

1B. SCIENTIFIC LAWS/THEORIES ARE UNCHANGED TRUTHS

pretest	10.3772	shift -.0526
posttest	10.4298	increases 1a attitude

2A. OBSERVATION IS THE BASIS OF SCIENCE. SCIENCE CAN ANSWER ONLY SOME QUESTIONS ABOUT NATURAL PHENOMENA.

pretest	11.0702	shift +.1053
posttest	10.9649	increases 2b attitude

2B. AUTHORITY IS THE BASIS OF SCIENCE. SCIENCE CAN PROVIDE CORRECT ANSWERS TO ALL QUESTIONS.

pretest	11.0175	shift -.3333
posttest	11.3509	increases 2a attitude

3A. THE SCIENTIFIC MANNER INVOLVES INTELLECTUAL HONESTY, OBJECTIVE OBSERVATIONS, AND A WILLINGNESS TO CHANGE ONE'S MIND ON THE BASIS OF SUFFICIENT EVIDENCE.

pretest	9.0702	shift -.9825
posttest	10.0526	increases 3a attitude

3B. THE SCIENTIFIC MANNER INVOLVES KNOWING ALL SCIENTIFIC TRUTHS AND BEING ABLE TO TAKE THE SIDE OF OTHER SCIENTISTS.

pretest	13.1140	shift -.0614
posttest	13.1754	increases 3a attitude

4A. THE VALUE OF SCIENCE IS IN GENERATING IDEAS/THEORIES. IT IS DEVOTED TO EXPLAINING NATURAL PHENOMENA.

pretest	9.0439	shift -.2368
posttest	9.2807	increases 4a attitude

TABLE 3:(Cont'd) MOORE & SUTMAN SCIENTIFIC ATTITUDE INVENT.

4B. THE VALUE OF SCIENCE IS IN DEVELOPING PRACTICAL USES/ TECHNOLOGIES. ITS DEVOTED TO SERVING HUMANKIND.

pretest	5.4561	shift +.2105
posttest	5.2456	increases 4b attitude

5A. SCIENTIFIC PROGRESS REQUIRES PUBLIC SUPPORT, AWARENESS AND UNDERSTANDING.

pretest	9.7807	shift -.1053
posttest	9.8860	increases 5a attitude

5B. THE PUBLIC DOES NOT NEED TO UNDERSTAND SCIENCE. SCIENCE DOES NOT AFFECT THE PUBLIC.

pretest	11.3860	shift +.0965
posttest	11.2895	increases 5b attitude

6A. I WOULD LIKE TO DO SCIENTIFIC WORK. ITS INTERESTING AND REWARDING.

pretest	7.6667	shift -.2105
poststest	7.8772	increases 6a attitude

6B. I WOULD NOT LIKE TO DO SCIENTIFIC WORK. ITS DULL, TOO HARD, AND TIME-CONSUMING.

pretest	9.5351	shift -.4737
posttest	10.0088	increases 6a attitude

EMO SCALE: EMOTIONAL REACTION TO SCIENCE
THIS IS THE SUM OF SCALES 4AB + 5AB + 6AB

pretest	52.8684	shift -.7193
posttest	53.5877	more positive toward science

INT SCALE: KNOWLEDGE ABOUT THE NATURE OF SCIENCE
THIS IS THE SUM OF SCALES 1AB + 2AB + 3AB

pretest	64.8596	shift -1.5175
posttest	66.3772	more knowledgable about science

TOTAL: THIS IS THE SUM OF 1AB + 2AB + 3AB + 4AB + 5AB + 6AB

pretest	117.7281	shift -2.2368
posttest	119.9649	

half (the "B's" after the numbers) would also reflect favorability.

On the SAI, this means the higher the mean on any subscale the more favorable the responses toward that attitude object. This is interpreted for the reader under the "shift" in the mean found with each subscale. Without interpreting which size of shift is significant, it is sufficient at this point to say that there appear to be conflicting results between the positive and negative items in the same attitude object for objects 2, 4, and 5. The apparent conflict is actually inverted for attitude object # 2, where the positive scale 2A shows a slight increase in the negative direction while the negative scale 2B shows a slight increase in the positive direction. The significance of the SAI will be discussed in Chapter 4.

WAVE KNOWLEDGE QUESTIONNAIRES (All n = 54 except Table 7)

Tables 4 through 8 are all change of knowledge tables related to wave phenomena. They were coded in a consistent method. Inter-coder reliability will be addressed in Chapter 4. A brief explanation of 5 category coding process is now appropriate. The coding procedure is a modified version of the one used by Anderson & Smith (1983) in their "Conceptions of Light and Color: Developing the Concept of Unseen Rays". Here is the scoring procedure used by the above tables:

Score	Nature of Response
+2	Response provided by the student is clearly correct.
+1	Response allows inference that the student is probably correct.
0	No response.

Score	Nature of Response
-1	Response allows inference that the student is probably incorrect.
-2	Response provided by the student is clearly incorrect.

All the knowledge tables are fairly easy to read for pretest-posttest comparison. All the knowledge tables (4-8) should be read from left to right, beginning with the best student responses on the left and ending with the "worst" student responses in the right column. The knowledge instruments used for these tables are in Appendix E. Brief comments will be given for each table with more interpretations given in Chapter 4.

OPEN-ENDED WAVE QUESTIONNAIRE (n = 54)

The data presented in Table 4 were obtained from the open-ended wave questionnaire given the first day and repeated the last week of class. This instrument was collected before the other knowledge questionnaires were given to the students so that they (other knowledge questionnaires) would not prompt answers for the open-ended questionairre from the vocabulary used in their more specific questions.

Looking at Table 4, one can observe a great difference between Q-1 and Q-2 as to the percentage of correct student responses on the pretest. This difference may be clarified

TABLE 4: OPEN-END WAVE QUESTIONS
(n = 54)
Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
Q-1: WHAT IS A WAVE?					
pretest	1.7	3.4	10.3	13.8	70.8
posttest	48.2	37.5	10.7	1.8	1.8
Q-2: GIVE SOME EXAMPLES OF WAVES.					
pretest	93.1	0.0	5.2	0.0	1.7
posttest	92.9	0.0	7.1	0.0	0.0
Q-3: WHAT CAN WAVES DO?(E.G. DESCRIBE SOME WAVE PROPERTIES)					
pretest	12.1	6.9	8.6	17.2	55.2
posttest	75.0	14.3	7.1	3.6	0.0
Q-4: WHAT COMMON EXPERIENCES DO YOU THINK YOU UNDERSTAND IN TERMS OF WAVES? EXPLAIN.					
pretest	29.3	6.9	38.0	13.8	12.0
posttest	76.8	16.1	7.1	0.0	0.0

by a brief explanation of the difference in the degree of difficulty involved with a successful student response to each question. The students did not do well on the pretest for Q-1 partly because a scientific definition was expected for a successful response. In this case, a successful response needed to include something about transmitting energy in order to be considered at least partially correct. Students scored high on Q-2 partially because it did not require "scientific" knowledge--anything from water to electromagnetic waves were acceptable. In Q-3, scientific wave properties such as diffraction, interference, fraction, etc. were considered correct. In Q-4, scientific wave properties, perhaps named in Q-3, were to be used in explaining common phenomena such as sky color, sunsets, mirages, echoes, resonance, etc. We can infer from the higher posttest scores on Q-1, Q-3, and Q-4 that a more sophisticated understanding of wave phenomena occurred.

WAVE DEFINITIONS (n = 54)

In Table 5, the data were obtained from the knowledge questionnaire that required the students to give answers to certain definitions related to wave phenomena. Therefore, more specific answers were required for a correct response than what was required for a correct response to questions in the open-ended knowledge questionnaire. While most students did not score well in the pretest, they identified several terms with a high degree of correctness. A partial explanation could be the great similarity between their common usage and the scientific usage. Students from the state of Michigan have a great deal of exposure to water wave phenomena. Therefore, the high percentage of correct responses in Q-4a, "crest" and Q-4b, "trough" could be examples of this similarity in usage. However, Q-11, "beats" is one term in which the students were perhaps misled because of a great difference between the common usage and the scientific usage of the term. About 40 % of the students use one of several common definitions of the term not related to wave phenomena. In every question, the posttest data shows a much greater understanding of terms used in relation to wave phenomena, at least on a recall level of complexity.

TABLE 5: WAVE DEFINITIONS
(n = 54)
Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
Q-1: VIBRATION					
pretest	8.6	5.2	19.0	19.0	48.7
posttest	60.7	28.6	5.4	5.3	0.0
Q-2: VELOCITY					
pretest	29.3	25.9	13.7	5.2	25.9
posttest	92.9	1.8	1.8	3.5	0.0
Q-3: FREQUENCY					
pretest	15.5	29.3	10.4	15.5	29.3
posttest	94.6	1.8	0.0	1.8	1.8
Q-4a: CREST					
pretest	77.6	1.7	8.7	3.4	8.6
posttest	100.0	0.0	0.0	0.0	0.0
Q-4b: TROUGH					
pretest	72.4	3.4	15.6	1.7	6.9
posttest	100.0	0.0	0.0	0.0	0.0
Q-5a: AMPLITUDE					
pretest	8.6	5.2	31.0	10.4	44.8
posttest	82.1	5.4	3.6	1.8	7.1
Q-5b: WAVELENGTH					
pretest	17.2	1.7	65.6	5.2	10.4
posttest	62.5	3.6	32.5	1.8	0.0
Q-6: TRANSVERSE WAVE					
pretest	15.6	5.2	55.1	3.4	20.7
posttest	91.1	7.1	1.8	0.0	0.0
Q-7a: LONGITUDINAL WAVE: COMPRESSION					
pretest	8.6	13.8	46.6	1.7	29.3
posttest	94.6	1.8	1.8	0.0	1.8
Q-7b: LONGITUDINAL WAVE: RAREFACTION					
pretest	8.6	8.6	67.3	0.0	15.5
posttest	94.6	1.8	1.8	0.0	1.8
Q-8a: STANDING WAVE: NODES					
pretest	5.2	8.6	63.8	1.7	20.7
posttest	85.8	8.9	1.7	1.8	1.8
Q-8b: STANDING WAVE: ANTINODES					
pretest	0.0	5.2	74.1	1.7	19.0
posttest	73.2	8.9	14.3	3.6	0.0

TABLE 5 (Cont'd) WAVE DEFINITIONS (n = 54)

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
Q-9a: INTERFERENCE: CONSTRUCTIVE					
pretest	6.9	10.3	39.7	6.9	36.2
posttest	89.3	8.9	0.0	0.0	1.8
Q-9b: INTERFERENCE: DESTRUCTIVE					
pretest	6.9	8.6	46.6	6.9	31.0
posttest	87.5	7.1	1.8	0.0	3.6
Q-10: RESONANCE					
pretest	0.0	0.0	72.4	0.0	27.6
posttest	80.4	14.3	1.8	3.5	0.0
Q-11: BEATS					
pretest	0.0	1.7	58.6	0.0	39.7
posttest	55.4	19.7	12.2	7.1	5.3
Q-12: REFLECTION					
pretest	12.1	19.0	39.6	13.8	15.5
posttest	89.3	1.8	3.5	5.4	0.0
Q-13: DIFFRACTION					
pretest	0.0	3.4	72.5	6.9	17.2
posttest	80.4	5.4	8.9	3.5	1.8
Q-14: REFRACTION					
pretest	1.7	12.1	72.4	0.0	13.8
posttest	75.0	10.7	8.9	1.8	3.6
Q-15: REVERSIBILITY					
pretest	1.7	5.2	67.2	6.9	19.4
posttest	66.1	7.1	25.0	0.0	1.8
Q-16: DOPPLER EFFECT					
pretest	1.7	6.9	69.0	3.4	19.0
posttest	67.9	16.1	1.7	12.5	1.8

WAVE SKETCHES & EXPLANATIONS (n = 54)

The data in Table 6 came from a wave questionnaire that required a greater depth of understanding than the definitions in Table 5. Instead of questions requiring primarily student recall, the students were required to sketch, label, and explain different wave phenomena. Once again, as in Table 5 the best pretest scores were related to terms in which the common and scientific usage were very similar. Q-2a, Q-2b and Q-2d are examples of this similarity. Higher posttest scores occurred on every question and could indicate that the students had learned to apply their understanding to more concrete situations through their sketching, labeling and explaining rather than only recalling definitions of somewhat abstract terms as exhibited in Table 5.

SPRING EIGHT-WEEK FOLLOW-UP (varied n, see Table 7)

In addition to Spring term pretest-postest data, Table 7 gives the students' responses to a "delayed" posttest, which is labeled "follow-up" on the table. The data apply to Spring term only, because Summer term was not long enough to assess knowledge retention over 8 weeks. This questionnaire used in this "delayed" posttest was the same instrument used in the Spring posttest which is contained within the data in Table 6. In some cases, the percentage for a score may be slightly higher in the 8-week follow-up.

This could be explained in part by the different size

TABLE 6: WAVE PATTERNS & EXPLANATIONS
(n = 54)
Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
GIVEN SLINKY:					
Q-1a: CREATE TRANSVERSE DISTURBANCE					
pretest	0.0	5.2	56.9	1.7	36.2
posttest	67.9	12.5	5.4	5.3	8.9
Q-1b: CREATE LONGITUDINAL DISTURBANCE					
pretest	0.0	3.4	55.2	0.0	41.4
posttest	69.6	5.4	8.9	5.4	10.7
LABEL WAVE FEATURES:					
Q-2a: CREST					
pretest	84.5	0.0	10.3	0.0	5.2
posttest	98.2	0.0	1.8	0.0	0.0
Q-2b: TROUGH					
pretest	74.1	0.0	19.0	0.0	6.9
posttest	98.2	0.0	1.8	0.0	0.0
Q-2c: AMPLITUDE					
pretest	24.1	1.7	17.3	3.4	53.5
posttest	96.4	0.0	3.6	0.0	0.0
Q-2d: WAVELENGTH					
pretest	41.4	1.7	19.0	3.4	34.5
posttest	94.6	0.0	1.8	3.6	0.0
RIPPLE TANK: SKETCH & EXPLAIN					
Q-3a: COMPARE DIFFRACTION: DIFFERENT SIZE OPENINGS					
pretest	1.7	0.0	81.0	5.2	12.1
posttest	67.9	8.9	10.7	10.7	1.8
Q-3b: SKETCH INTERFERENCE: TWO POINT SOURCES					
pretest	0.0	1.7	69.0	1.7	27.6
posttest	44.7	32.1	12.5	8.9	1.8
Q-3c: REFRACTION: DEEP TO SHALLOW WATER					
pretest	0.0	5.2	72.4	0.0	22.4
posttest	64.3	14.3	10.7	8.9	1.8
GIVE BRIEF EXPLANATION:					
Q-4a: HEARING A SOUND AROUND THE CORNER OF A HALLWAY					
pretest	8.6	24.1	19.1	10.3	37.9
posttest	80.4	14.2	3.6	1.8	0.0

TABLE 7: SPRING EIGHT WEEK FOLLOW-UP

WAVE PATTERNS & EXPLANATIONS: KNOWLEDGE RETENTION
Pretests (n = 35), Posttests (n = 33), & FOLLOW-UP (n = 31)
FREQUENCY DISTRIBUTION IN PERCENTAGES.

RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
GIVEN SLINKY:					
Q-1a: CREATE TRANSVERSE DISTURBANCE					
pretest	0.0	5.7	60.0	2.9	35.4
posttest	63.6	18.2	6.0	6.1	6.1
FOLLOW-UP	64.5	6.5	3.2	3.3	6.5
Q-1b: CREATE LONGITUDINAL DISTURBANCE					
pretest	0.0	0.0	62.9	0.0	37.1
posttest	69.7	9.1	12.1	3.0	6.1
FOLLOW-UP	67.7	6.5	3.3	12.9	9.7
LABEL WAVE FEATURES:					
Q-2a: CREST					
pretest	74.3	0.0	17.1	0.0	8.6
posttest	97.0	0.0	3.0	0.0	0.0
FOLLOW-UP	100.0	0.0	0.0	0.0	0.0
Q-2b: TROUGH					
pretest	57.1	0.0	31.4	0.0	11.5
posttest	97.0	0.0	3.0	0.0	0.0
FOLLOW-UP	96.8	0.0	3.2	0.0	0.0
Q-2c: AMPLITUDE					
pretest	20.0	0.0	22.9	5.7	51.4
posttest	93.9	0.0	6.1	0.0	0.0
FOLLOW-UP	87.0	0.0	3.2	3.3	6.5
Q-2d: WAVELENGTH					
pretest	25.7	0.0	31.4	5.7	37.2
posttest	93.9	0.0	6.1	0.0	0.0
FOLLOW-UP	96.8	0.0	0.0	3.2	0.0
RIPPLE TANK: SKETCH & EXPLAIN					
Q-3a: COMPARE DIFFRACTION: DIFFERENT SIZE OPENINGS					
pretest	2.9	0.0	85.7	2.9	8.6
posttest	60.6	12.1	12.2	12.1	3.0
FOLLOW-UP	61.3	16.1	6.5	12.9	3.2
Q-3b: SKETCH INTERFERENCE: TWO POINT SOURCES					
pretest	0.0	0.0	82.9	0.0	17.1
posttest	42.4	33.3	15.2	6.1	3.0
FOLLOW-UP	32.3	48.2	3.3	6.5	9.7

TABLE 7: (Continued) SPRING EIGHT WEEK FOLLOW-UP(n = 54)

Q-3c: REFRACTION: DEEP TO SHALLOW WATER					
pretest	0.0	2.9	80.0	0.0	17.1
posttest	63.3	18.2	12.2	3.0	3.0
FOLLOW-UP	58.0	12.9	6.5	12.9	9.7
GIVE BRIEF EXPLANATION:					
Q-4a: HEARING A SOUND AROUND THE CORNER OF A HALLWAY					
pretest	14.3	8.6	22.9	11.4	42.8
posttest	75.8	18.2	3.0	3.0	0.0
FOLLOW-UP	71.0	19.3	0.0	9.7	0.0

student populations given at the top of the table. However, the larger increases appear to occur for other reasons. These changes and the higher knowledge retention will be interpreted in the next chapter.

WAVE KNOWLEDGE TRANSFER (n = 54)

The knowledge questionnaires use for Table 8 were given the first and last week of the course each term. These questionnaires appeared to require a higher level of understanding for a correct answer than those used in the other data tables 4 to 7. They contained questions related to certain "wave" phenomena knowledge not clearly treated as such in the course and/or questions that are related to a higher complexity level of reasoning. For example, the understanding of "Why sunsets are red?" requires more than one concept to explain it.

Here, the end-of-class wave knowledge questionnaire is called "transfer" rather than "posttest" to emphasize that there was no clear treatment or time frame in the course that these "test" questions followed. By "no clear treatment", it is meant that the multiple concepts required

TABLE 8: WAVE KNOWLEDGE TRANSFER
(n = 54)
Pretests & Transfers: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
GIVE BRIEF EXPLANATION:					
Q-4b: LIGHT					
pretest	0.0	0.0	54.3	8.6	37.1
TRANSFER	41.9	38.7	0.0	12.9	6.5
Q-4c: ELECTRICITY					
pretest	0.0	0.0	60.0	2.9	37.1
TRANSFER	35.5	29.0	3.7	6.5	19.3
Q-4d: HEAT					
pretest	5.7	5.7	37.1	14.4	37.1
TRANSFER	100.0	0.0	0.0	0.0	0.0
Q-1a: WATER WAVE					
pretest	0.0	0.0	17.1	0.0	82.9
TRANSFER	80.5	3.3	9.7	0.0	6.5
Q-1b: SPECK MOVEMENT (transverse wave)					
pretest	0.0	2.9	20.0	2.9	74.2
TRANSFER	80.5	0.0	13.0	0.0	6.5
Q-2a: AIR WAVE					
pretest	0.0	0.0	40.0	2.9	57.1
TRANSFER	32.3	3.2	16.1	9.7	38.7
Q-2b: SPECK MOVEMENT (transverse wave)					
pretest	0.0	8.6	40.0	0.0	51.4
TRANSFER	35.5	0.0	16.1	6.5	41.9
Q-3: WAVE & PIPE LENGTH					
pretest	0.0	2.9	34.3	42.8	20.0
TRANSFER	35.5	38.8	13.0	9.7	6.5

for a correct answer were never clearly related to each other or to wave phenomena as part of the course instruction. The phrase "time frame" means that the multiple concepts required for a correct response may not occur contiguously in the course. For example, Concept A could have been presented the first week, Concept B the third week, and Concept C the fifth week. A question requiring the use of all three concepts together in one answer would involve different lengths of time for the students' knowledge to be retained. Therefore, with no clear treatment or time frame, it would require a high degree of knowledge integration skills on the part of the students to answer successfully some of these questions.

Although some significant transfer of knowledge appears to have occurred, Q-4d may not exhibit true transfer of knowledge as defined above. First, the concept of heat transfer by radiation was used in the course although explicit references to previous wave phenomena were not made by the lecturer. Secondly, certain "heat wave" terms could have a common usage by the students without the students achieving a higher complexity of understanding. Some references will be made to this table in Chapter 4.

SCIENCE LEARNING & TEACHING SKILLS SURVEYS (n = 54)

The data for Table 9 were generated from the skills section of the author's background-attitude-skills survey. Different types of learning and teaching activities were rated by the students as they perceived the present and potential usefulness of the activities to themselves.
One should not infer that this table represents the actual learning and teaching skills that the students possess but the table represents an indication of the direction of possible growth of their skills. Further discussion supplemented by other data will occur later in Chapter 4.

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TABLE 9: SCIENCE LEARNING & TEACHING SKILLS
(n = 54)
RATING LEARNING & TEACHING ACTIVITIES FORM BACKGROUND-ATTITUDE QUESTIONNAIRE

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 1 = not helpful; 2 = slightly helpful; 3 = somewhat helpful; 4 = very helpful; 5 = extremely helpful.

EVALULATION OF LEARNIING ACTIVITIES BY STUDENTS BASED ON THEIR PAST SCIENCE EXPERIENCES.

	1	2	3	4	5
LEARNING:					
Q-19: LABORATORY WORK					
pretest	3.7	11.1	33.3	33.3	18.5
posttest	0.0	5.6	7.4	42.6	44.4
Q-20: DEMONSTRATIONS: LECTURE & LABORATORY					
pretest	1.9	13.0	20.4	44.4	20.4
posttest	0.0	0.0	14.8	44.4	40.7
Q-21: FILMS					
pretest	1.9	29.6	48.1	16.7	3.7
posttest	11.5	15.4	38.5	25.0	9.6
Q-22: LECTURES					
pretest	0.0	7.4	27.8	57.4	7.4
posttest	0.0	5.6	35.2	53.7	5.6
Q-23: DISCUSSIONS					
pretest	0.0	5.6	35.2	46.3	13.0
posttest	0.0	1.9	35.2	42.6	20.4
Q-24: TEXTBOOKS					
pretest	0.0	14.8	50.0	29.6	5.6
posttest	1.9	11.3	34.0	47.2	5.7
Q-25: PROBLEM SETS					
pretest	1.9	17.0	37.7	30.2	13.2
posttest	0.0	5.6	38.9	44.4	11.1
Q-26: STRUCTURED REVIEWS PRIOR TO EXAMS					
pretest	0.0	7.4	35.2	27.8	29.6
posttest	1.9	1.9	3.8	28.3	64.2

TABLE 9: (Cont'd) SCIENCE LEARNING & TEACHING SKILLS

RATING LEARNING & TEACHING ACTIVITIES FROM BACKGROUND-ATTITUDE QUESTIONNAIRE

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 1 = not helpful; 2 = slightly helpful; 3 = somewhat helpful; 4 = very helpful; 5 = extremely helpful.

POTENTIAL VALUE OF TEACHING ACTIVITIES PERCEIVED BY PROSPECTIVE-TEACHING STUDENTS

	1	2	3	4	5
Q-42: LABORATORY APPROACH					
pretest	0.0	12.2	28.6	38.8	20.4
posttest	0.0	3.8	45.8	42.3	48.1
Q-43: DEMONSTRATIONS & FILMS					
pretest	0.0	2.0	26.0	54.0	18.0
posttest	0.0	5.8	7.7	44.2	42.3
Q-44: LECTURES					
pretest	0.0	12.0	42.0	40.0	6.0
posttest	1.9	17.3	48.1	26.9	5.8
Q-45: DISCUSSIONS					
pretest	0.0	6.0	30.0	48.0	16.0
posttest	0.0	5.9	35.3	39.2	19.6
Q-46: TEXTBOOKS					
pretest	0.0	12.0	32.0	42.0	14.0
posttest	1.9	9.6	32.7	42.3	13.5
Q-47: RESOURCE BOOKS, MAGAZINES, ETC					
pretest	0.0	12.0	18.0	50.0	20.0
posttest	3.9	23.5	41.2	19.6	11.8
Q-48: STRUCTURED REVIEWS PRIOR TO EXAMS					
pretest	2.0	10.0	28.0	40.0	20.0
posttest	0.0	1.9	19.2	28.8	50.0

Looking at Table 9, the learning-skills activities that had the largest increases at the two highest levels of the Likert scale ("very helpful" and " extremely helpful") were the Laboratory Work (Q-19), Demonstrations (Q-20), and Structured Reviews (Q-26). If we combine these two levels for each question, the student responses at these levels increased from 51.8% to 87% for the Lab Work, from 64.8% to 85.1% for the Demonstrations, and from 57.4% to 92.5% for the Structured Reviews with the largest part of each gain being at the highest level: "extremely helpful".

The teaching-approach categories that had the largest increases were the teaching activities that would parallel the above student learning activities. Combining the two highest levels of the Likert scale, the increase in student responses for the two levels for each category would be from 59.2% to 90.1% for the Laboratory (Q-42), from 72% to 86.5% for the Demonstrations (Q-43) and from 60% to 78.8% for Structured Reviews. Once again the largest part of each gain was at the highest: "extremely helpful". In addition, the students' perception of the usefulness of lecture as a teaching approach (Q-44) decreased from 46% to 32.7% at the two highest rating levels with almost all of the decrease at the "very helpful" level. The highest level ("extremely helpful") had few responses in both the pretest and posttest, remaining at about 6%. Further discussion of the skills survey will occur in Chapter 4.

<u>Acquisition & Analysis of Interviews & other Ethnographic Data</u>

The four principal sources of ethnographic data utilized in this study are:

1. Special Research Exercise: open-ended questions
2. Interviews: open-ended questions based on information on students' previous responses
3. Transfer of Learning/Teaching Skills Exercise: open-ended questions

4. Anonymous Student Evaluation: open comments

All four sources aided the research by describing the effects of this course on the attitudes, knowledge, and skills of prospective elementary teacher regarding science and science teaching. Each source will be described in terms of how the data was categorized and some examples of student quotes from each instrument. Before describing each source, a general description of how the data was coded for each source will be discussed.

A tremendous amount of descriptive data was obtained from the above sources. Most of it is in Appendicies A through D and it is not practical to include it in this chapter. In addition to the written exercises, the student interviews were transcribed from audio tapes. How to categorize the variety of responses into meaningful data was a difficult process. The questions asked were marginal in forming categories because the divergence of responses to open-ended questions can be wide. Although the categories for each data source varied, the same general technique worked best for all four sources. Although time consuming, this technique involved reading through all the written data and underlining key words in the students' responses and using those as preliminary categories. If responses did not group well in the initial categories, then new categories were created, existing categories were modified (usually becoming more generalized) or if necessary discarded. Not all sources have the same categories, but they all have some categories relating to attitudes, knowledge, and skills. Under the category in each source, there are student quotes taken from the students' responses on the written exercise or from the interview transcripts of that student.

SPECIAL RESEARCH EXERCISE (n = 54)

The first open-ended exercise was called "Special Research Exercise" (Appendix A). This exercise was given to the students approximately half-way through each term. The students were asked to reflect on:

1. How did the laboratory experience influence their learning of waves, sound and light?
2. How did the laboratory experience influence their attitude and learning skills?
3. How did the laboratory experience compare to other aspects of the course?

Since this was a take-home exercise to be returned in several days, reference to their previous lab reports was permitted and encouraged. According to the above described process, the students' written answers were coded into the following categories:

1. Understanding Waves: Sound & Light
2. Effects on Attitude
    a. Good Role Model: High Teacher Concern
    b. Less Anxiety, More Enjoyment & Confidence
3. Effects on Learning & Teaching Skills
    a. Good Role Model: Teaching Techniques & Resources
    b. Scientific Processes: Activity-Oriented Skills
    c. Easier Learning: Concrete Lab Experiences
    d. Small-Group Environment: More Individual Involvement
    e. Relevance to Daily Life

4. Lab Compared to Other Course Experiences

5. Course Compared to Other Classes: Science, Methods

6. Class Design: Parts Complementary & Reinforcing

7. Suggestions for Improvememts

Several random examples of student responses are now given in relation to several of the above categories.

Under category 1, B.DEL., 7-8-85:

"The best demonstration of longitudinal waves was the long suspended slinky which periodically contained white balls. These procedures always come to mind as we later built on the wave theory."

Under category 2a, M.L.,4-29-85:

"You guys go out of your way to make sure understanding occurs. You really care. It makes me care and I feel you are a prime example of what kind of teacher I want to be!"

Under category 2b, J.C.,4-29-85:

"I have enjoyed science for the first time in a long time. I hope I can present science in the same way to kids in my classroom."

Further quotations from this exercise are given in the Ethnographic Data, Appendix A.

INTERVIEWS (n = 22)

Interviews were given to almost all (over 90 %) of the students who had indicated the highest anxiety on the Author's attitude section of the Background-Attitude-Skills Survey administered at the beginning of the course. For comparison, some students who had not indicated high anxiety were interviewed for comparison. The total number of students interviewed equaled 40% of the total student population or 22 students.

The interviews were recorded on audio tape. Transcripts were made from the tapes. Quotations were coded from the transcripts according to the above described process and listed under the general categories of:

1. Change in Attitude
2. Change in Knowledge
3. Change in Learning/Teaching Skills

Several random examples of student responses are now given in relation to the above categories.

Under category 1, B.DEL., 7-24-85:

INT: "Would you recommend this course to someone with high anxiety towards science?" B.D.: "Yes." INT: "Why?" B.D.: "You wouldn't have anxiety anymore. A class you'd enjoy going to although I had a high anxiety to start out with. The atmosphere of the classroom is very positive, pro-learning, very helpful, very non-threatening, felt you wouln't be ridiculed."

Under category 2, S.B., 7-24-85:

"Lab taught alot of these skills and gives you much more awareness when you're observing things. You just can't take things for face value anymore. You want to know why--why the sky's blue--those kinds of things you always wonder about--but I observed them in a different way before I took this class."

Under category 3, P.C., 7-23-85:

"Unfortunately I had the idea of having a classroom where I'd be doing the lecture, very structured, very didactic. I'd be lecturing and my students would be listening. I've got to change my mind about this and this course has helped because I've understood through my own lab experience--by working with other students and hearing my own peers speaking about it. In my own class, I'll encourage my students to talk among themselves. So it was a good experience with this approach. It has changed my mind about how to teach."

Further quotations from the interviews conducted in the Spring and Summer are in the Ethnoraphic Data, Appendix B.

TRANSFER OF LEARNING/TEACHING SKILLS (n = 54)

This open-ended research exercise was called Transfer of Learning/Teaching Skills. It was given as a take-home assignment during the last week of each term, the students were asked to reflect upon and to summarize their course knowledge in reference to waves. This would demand, in part, that the students do some significant Transfer of Knowledge. In addition, the exercise required that the students reflect on how the lab experience may have influenced their Science Learning Skills and Potential Science Teaching Skills. The answers to the last part of this exercise were coded according to the previously described process as:

1. "Good Role Model: High Teacher Concern"
2. "Good Role Model: Teaching Techniques & Resources"
3. "Scientific Processes: Activity-Oriented Skills"
4. "Easier Learning: Concrete Experiences"
5. "Small-Group Environment: More Individual Involvement"
6. "Less Anxiety, More Enjoyment & Confidence in Teaching"

Several random examples of student responses are now given for several of the above categories.

Under category 1, M.L., 6-6-85:

"... you have been a great help in understanding this class. You are a fine example and I hope that I can do as fine a job as you have of teaching. You guys go out of your way to help us understand and we have fun while we learn."

Under category 2, B.D., 6-6-85:

" Lab was an essential part of this class and it greatly helped me learn the topics taught. The labs also gave me a generous amount of ideas to use for my teaching experiences. There wan't very much that would have to be changed to incorporate most of those labs to a class of younger students."

Under category 3, M.C., 6-6-85:

"The laboratory experience allowed me to become a scientist --I had to observe, predict and apply my knowledge."

Further quotes from the Spring and Summer terms are in the Ethnographic Data, Appendix C.

ANONYMOUS STUDENT EVALUATIONS (n = 41)

On the last day of class, the university requires that "SIRS Forms", anonymous student evaluation forms, be given to the students. On these forms, there is a place for students to write comments if they wish. The instructors highly encouraged them of offer some feedback. Most students (about 76%) did write some comments. In addition to the above Transfer of Learning/Teaching Skills categories, the anonymous student responses were coded according to the previously described process in the following areas:

1. "Comparison with other Classes"
2. "Class Design"
3. "Suggestions for Improvement"

Examples of anonymous student responses are given for each numbered category.

Under category 1, an anonymous quote:

"Super class! One that I enjoyed more than any other science class I've had. I began this class dreading taking it. It was so much more enjoyable and I learned a tremendous amount of information about Physical Science and feel much more competent in teaching science."

Under category 2, an anonymous quote:

"I think they did a super job! . . . The way everything

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complemented each other--lab, textbook, lecture, etc. was terrific. I gained alot of good ideas for my elementary classroom"

Under category 3, an anonymous quote:

"The only complaint is that some labs went very fast for me --not giving me time to absorb the concepts as I did them. However, I understand this was unavoidable in order to cover all necessary material."

Further anonymous quotations are given in Appendix D.

OTHER SOURCES

To aid with the course description and research triangulation, other sources of Ethnographic data were collected. These include written documents of course materials, outside observers' field notes of the wave lab treatment, an audio tape and videotape of the wave lab treatment. They will be discussed where appropriate in the following chapter.

In summary, Chapter 3 presented a brief review of the major aspects of both the research questions and course design. It described in detail the research design: anticipated criticisms, instrument descriptions, and data collection procedures. It presented a wealth of data and referred to more data in the appendicies. Chapter 3, however, did not provide detailed data interpretation or synthesize it into several general assertations. Assertations must be verified or refuted by evidence and should lead to some conclusions about the effects of this course on its prospect-elementary teachers. This will be done in Chapter 4.

Chapter Four

Data Interpretation

This chapter interprets the data described in Chapter 3 by synthesizing it into several general assertions. Each area of concern---attitudes, knowledge, and skills---will be addressed by several assertions that will be either supported or weakened by evidence from the data. Before stating any assertions, a discussion of the reliability and validity of the statistical instruments and ethnographic methods will occur. Only data that exhibited appropriate levels of reliablility and validity as described in this first section will be used in the assertions section.

Reliability and Validity

AUTHOR'S BACKGROUND-ATTITUDE-SKILLS SURVEY: Paired t-Test

The author's attitude-skills survey was constructed in part because after using the Moore & Sutman Scientific Attitude Inventory (SAI) in a pilot study, he had a tendency to agree with Munby (1983). Both, the author and Munby agree that there are problems in the SAI coding scheme and that it is not clear what attitudes the instrument is actually measuring. This is discussed in the SAI section.

The author also wished to address directly certain attitudes that the SAI did not clearly do. The author felt, first of all, that his survey's questions (Appendix E) were low-i

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low-inference, self-reporting questions in which the students' responses could be reported clearly. Secondly, he felt that some reliability could be developed by cross-checking for consistence the survey results with the ethnographic methods. In addition, similarity in student responses from the author's survey, and the ethnographic approaches could be compared.

The statistical Paired t-Test was performed on all the survey's questions. The value of the t in a t-test is not important in itself, but from it one can determine the probability associated with the observed difference in the sample means. The paired t-test compares the means on two variables from the same sample. In this study, it is used to compare the means from the same students at different times. In other words, it compares "pre-test" results with "post-test" results with the course as the "treatment" in between the "tests".

Listed below are only those survey questions in which the "2-tail probability" for the t-value is not more than 0.05. Only these questions in which the author can be at least 95% sure that the observed difference in means is not merely due to sampling error or chance are used in the Assertions Section that follows in this chapter.

From Table 2 on Attitudes:

	t-value	degrees of freedom	2-tail prob.
Q-30 COURSE DIFFICULTY	6.51	53	.000
Q-31 COURSE INTEREST	-3.04	53	.004
Q-32 SCIENCE ENJOYMENT	-4.90	53	.000
Q-33 SCIENCE ATTITUDE	-6.46	53	.000
Q-34 SCIENCE ANXIETY	-6.45	53	.000
Q-35 PHYSICS ANXIETY	-8.11	53	.000
Q-49 ANTICPATED ENJOY. SCI. TEACH.	-2.09	48	.044
Q-50 TIME DEVOTED TO SCI. TEACHING	-2.40	47	.021
Q-41 COMPETENCE FELT SCI. TEACH.	2.33	9	.045

From Table 9 on LEARNING SKILLS:

Q-19 LABORATORY WORK	-5.28	53	.000
Q-20 DEMONSTRA-TIONS: LEC.& LAB.	-3.80	53	.000
Q-26 REVIEW PRIOR TO EXAM	-5.00	53	.000

From Table 9 on Teaching Skills:

Q-42 LABORATORY APPROACH	-4.69	48	.000
Q-43 DEMONSTRA-TIONS & FILMS	-3.06	48	.000
Q-47 RESOURCE BOOKS, ETC.	3.35	48	.002
Q-48 REVIEW PRIOR TO EXAM	-3.74	48	.000

MOORE & SUTMAN SCIENTIFIC ATTITUDE INVENTORY (SAI): Paired t-Test

Although this instrument has been used in many studies that have attempted to assess certain types of scientific attitude, it was used by this author with great reservation. First, it did not address some attitudes the author desired to measure. Secondly, the attitudes it did address were done only through high inference. Thirdly, there is substantial doubt that it really measures what it claims to be measuring. In spite of these reservations, the author could see the SAI's potential worth if the above reservations were unfounded. Following is a detailed discussion of some problems related to this instrument including the author's experience in using the SAI.

Munby (1983) in his "Thirty Studies Involving the Scientific Attitude Inventory (SAI): What Confidence Can We Have In This Instrument?" challenged the validity of the SAI. By using the conceptual perspectives developed in his study, he showed that many of the items which might be thought to indicate certain attitudes according to the SAI coding can be interpreted very differently. He stated that by using his "clue structure" approach, "the discrepant tive studies can be explained." This meant in part that many of the SAI items do not measure the attitudes that they claim to measure. Munby's report concluded that we cannot be sure what the SAI measures and that "it needs reworking before it can be used with confidence."

In addition, the author of this study took strong exception to the SAI's "belief" that scales 4A and 4B are opposite attitudes. Scale 4A is coded as "Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects." Scale 4B is coded as " Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses." Although the author would agree with the SAI that the two codes represent different values, the author does not agree with the SAI in its coding that Scale 4B is a negative attitude in direct opposition to Scale 4A.

The statistical Paired-T test was done on the SAI's attitude scales. Of the 12 attitude scales, only 3A had a probability that was less than .05, while the next lowest probability was 6B with a .142 probability that the difference in the pre-test and post-test means was due to chance. Listed below is Scale 3A which was coded as indicating an attitude with the following characteristics: "To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence."

From Table 3: MOORE & SUTMAN SAI

	t-value	degrees of freedom	2-tail prob.
SCALE 3A	-3.10	53	.003

The inter-related construction of the SAI scales is in pairs. The scale 3B is the negative counterpart to scale 3A, but scale 3B had a 2-tail probability of 0.778 which indicates that the difference in its means from pretest to posttest was due to chance. This fact causes some doubt as to what scale 3A really means irrespective of its low probability.

Although the author had hoped that the SAI would be useful in this research, subsequent experience has shown that the author's stated reservations to be well founded. Recalling the author's reservations about the SAI: 1) it does not address some attitudes that the author desired to measure, 2) the attitudes it did measure were done only through high inference, and 3) there is substantial doubt that it really measures what it claims to be measuring. Results from the SAI showed a lack of significant change in attitudes toward science. These results were contrary to all other data sources. The author's surveys and ethnographic methods showed consistent change in scientific attitudes. For example, in-depth interviews of 22 students indicated significant change in some attitudes but the SAI does not indicate clearly any changes in attitudes. In addition to the above reservations, the author believes that SAI survey questions coded under the same attitude scales are not only sometimes questionnably related, but more critically these questions tend to counteract each other and therefore dampen any change that could occur in k

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that attitude scale. These problems must be left to other research.

The discussion in this section and other sections renders in the author's opinion little reason to use the SAI as evidence for supporting or weakening any assertions made in this study.

KNOWLEDGE QUESTIONNAIRES: INTER-CODER RELIABLILITY

In assessing the validity and reliability of the coded-knowledge questionnaires, three different coders were used. All the questionnaires were coded by two coders and a third coder coded a random sample. Each coder was given a brief training session. The coders were given first the coding categories and the correct responses to each question they were to code. Recalling the code from Chapter 3, we remember that 2 = correct response, 1 = inferred correct, 0 = no response, -1 = inferred incorrect, -2 = incorrect response. Thus, the coder was forced to make some type of decision as to correctness if any response was given to a question. Secondly, each coder was given several examples of responses to illustrate the difference between respones that were clearly correct or incorrect and those that were inferred to be correct or incorrect. Thirdly, the coders tried an example on their own. Then it was discussed with the author to minimize any immediate problems with the coding.

The questionnaires were coded independently by each coder. They agreed initially on 98% of the responses.

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After reviewing the categories and discussing their differences, they were able to eliminate their 2% disagreement. The results of their coded knowledge questionnaires are in Chapter 3.

ETHNOGRAPHIC METHODS: TRIANGULATION

The open-ended Special Research Exercise, the Interviews, the open-ended Transfer of Learning/Teaching Skills, and the Anonymous Student Evaluations were the four major sources of ethnographic data for describing the students' attitudes, knowledge, and skills. Information from these sources was compared for similarity. This use of multiple sources of information to cross-check or supplement each others' results is called TRIANGULATION. This was the major ethnographic process for verifying the reliability and validity of observations. Erickson (1986) described articulately the use of this process of triangulation in his chapter in the Handbook of Research on Teachning. For example, this excerpt described how Erickson perceives part of the process for generating and testing the validity of assertions:

> A report of fieldwork research contains many empirical assertions that vary in scope and in level of inference. One basic task of data analysis is to generate these assertions, largely through induction. This is done by searching the data corpus--- ... Another basic task is to establish an evidentiary warrant for the assertions one wishes to make. This is done by reviewing the data corpus repeatedly to test the validity of the assertions that were generated, seeking disconfirming evidence as well as confirming evidence (Erickson, p. 146).

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The results from this study's four primary ethnographic sources were part of the data corpus that was reviewed repeatly to generate assertions and was used to test the validity of those assertions. In addition, these results were found to be very similar and compared well with the coded-knowledge questionnaires and the author's background-attitude-skills survey. Copies of the open-ended Special Research Exercise and Tranfer of Learning/Teaching Skills are in the Appendicies A and C respectively. In addition, categorized quotes from all four sources are in the Appendicies A,B,C and D .

Gorden (1980) in his Interviewing: Strategy,Techniques and Tactics expounds some useful insights into ethnographic reliability and validity. He states:

> Reliability of any measure or observation refers to the probability that an observation if repeated at a different time by the same person, or at the same time by another competent observer, will give the same result (Gorden, p. 40).

In this study, we would find different students give similar responses on the same ethnographic exercises given at the same time and we would find the same students giving similar responses on four different ethnographic exercises given at different times. Thus indicating a high level of reliability as provided by triangulation of this study's ethnographic sources.

Gorden continued by describing his concerns about the problem of ethnographic validity and its relation to reliabilty. He describes:

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> The problem of validity becomes clear when we realize that most observations are indirect . . . we cannot directly see another person's attitude, but we use that person's response to questions, to projective tests, or his body movements as indirect indicators of the attitude hidden inside. It is clear that for observations to be valid they must be reliable, but the fact that observations are reliable is no guarantee that they will be valid. So we can say that reliability is a necessary but not sufficient condition for validity (Gorden, p. 40).

In addition to the high degree of validity provided through triangulation of the 4 ethnographic data sources, this study also addressed the question of selection validity. High Selection validity can be obtained by taking a random sample large enough to adequately represent the total population to which we want to generalize.

In this research, the selection validity is very high. For the Open-ended Special Research Exercise, the open-ended Transfer of Learning/Teaching Skills and Anonymous Student Evaluations, the whole of both classes or 100 % of the student population was used. For the Interviews, the primary target population was students who had indicated the highest science anxiety on the author's survey and the secondary target was the total student population. Over 90 % of the highest-anxiety students were interviewed and about 40 % (or 22 individuals) of the total student population was interviewed.

Only data that has shown reliability and validity through triangulation and a "2-tail probability" of 0.05 on the paired t-test will be used as evidence to support or weaken the assertions in the next section. As the assertions' discussions occur, it will become apparent that all 4 ethnographic sources will be used as data for each assertion. In addition, data from the statistical instruments will be used that corresponds to the approprate attitude, knowledge and skills assertions.

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RESEARCH ASSERTIONS

This section represents a further analysis of the data from this research. However, it differs from Chapter 3 in that it is interpretive, more like the "discussion" section found in reports of more traditional research.

In this section, assertions will be stated which are derived from the data presented in Chapter 3. Data supporting these assertions will be highlighted in summary form and each assertion will be discussed in terms of relevant research literature.

An assertion is an inference based on research data that strongly supports its intent. Because of the complex nature of the system being studied (e.g., a university science class with a large number of diverse students) conflicting data exists. Thus some data may support an assertion while counter evidence may weaken it. Following each assertion, both supporting and counter evidence will be presented when both exist. However, for all assertions listed, the supporting data substantially outweighs the counter evidence.

Several assertions about the teaching and learning of science will be made regarding students' attitudes, knowledge and skills. The order of discussion on assertions will be: 1) attitudes, 2) knowledge and 3) skills.

Attitude Assertions

ATTITUDE ASSERTION #1: Most students' anxiety about the learning and teaching of science decreased during this course.

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In this Assertion, anxiety includes the science attitudes related to expectations, motivation, confidence, comfort, and interest regarding the laerning and teaching of science.

SUPPORT: Support for this assertion is provided by both the statistical and the ethnographic data. Key data are summarized as follows:

1. ATTITUDE SURVEY section from the author's background-attitude-skills survey (Table 2).

Each scale below is a 5-point Likert-type scale ranging from the most negative response on the left, through intermediate values to the most positive response on the right. All three of the following questions show that higher percentage of the students' responses are occurring toward the more positive end of the scale in the posttest compared to the pretest, thereby giving support to the assertion.

Q-34: SCIENCE ANXIETY

	VERY HIGH		MODERATE		VERY LOW
pretest	27.8	24.1	24.1	16.7	7.4
posttest	0.0	11.1	29.6	38.9	20.4

Combining the two highest levels on anxiety, this data show that 51.9% of the students indicated high anxiety toward learning science at the start of the course while only 11.1% of the students indicated this anxiety at the end. A similar change occurs in the following question, Q-35, where toward physics dropped from 68.5% of students on the pretest to only 13% of the students on the posttest.

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Q-35: PHYSICS ANXIETY

	VERY HIGH		MODERATE		VERY LOW
pretest	37.0	31.5	16.7	13.0	1.9
posttest	1.9	11.1	16.6	59.3	11.1

Further support for this assertion is given by a corresponding increase in the enjoyment of science in Q-32. On the pretest, 33.4% of the students recorded the two highest levels of enjoyment. On the posttest, 77.8 % of the students were in the two highest levels of enjoyment.

Q-32: SCIENCE ENJOYMENT

	VERY LOW		MODERATE		VERY HIGH
pretest	16.7	16.7	33.3	16.7	16.7
posttest	1.9	7.4	13.0	46.3	31.5

2. BACKGROUND SURVEY section from the author's background-attitude-skills survey (Table 1).

The question (Q-15) below indicates that almost 3/4 of the students would never have taken this class if it had not been required. This question was part of a survey given on the first day of class and could be another indication of the students' high anxiety on entering this course. This is consonant with the previous attitudinal items.

Q-15: WHY DID YOU ENROLL IN THIS CLASS?

72.2	A Major or College Requirement
25.9	A Requirement, but also wanted to
1.9	No Requirement, but wanted to

3. ETHNOGRAPHIC METHODS.

The following student quotations from the four Ethnographic Methods employed in this research compare well with

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the above survey questions by illustrating a high science anxiety and low science enjoyment upon entering this course. They also indicate a shift toward less anxiety and toward greater enjoyment on the part of the students as a result of this course, thus supporting the above assertion. Only a few representative examples from each ethnographic method will be given here as evidence of support. The reader is encouraged to read the numerous supportive responses in the Appendix that is indicated for each method.

A note of caution is appropriate before looking at the ethnographic data. The number of total quotations listed under a particular category is deceptive for several reasons. Statements by the students about their attitudes, knowledge, and skills are intertwined and can often only be extracted according to these categories artificially. For example, positive changes in student attitudes be may listed in places other than the attitude categories. That is, if a student's statement emphasizes a greater change in knowledge than attitudes and skills, (even though it also contains reference to positive changes in attitudes and skills) the statement may only be listed in a knowledge category. This should become clearer as the following ethnographic methods are discussed.

SPECIAL RESEARCH EXERCISE (Appendix A): Although student quotations related to the development of greater positive attitudes toward science and science teaching are found throughout Appendix A, 24 out of a possible 54 students

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volunteered very clear statements about their positive change in attitudes.

Twenty-four students out of a possible fifty-four students may not look like a profound number, but readers should consider that the statements were constructed and volunteered by the students and that student responses were listed in an attitude category only if they clearly emphasized a greater change in attitude than in knowledge or skills. In other words, to list a student's statement as an example for the attitudes' categories required to a large degree an artificial extraction of that quotation from an intertwined attitudes-knowledge-skills statement that had been volunteered by that student. Therefore, 24 students is lower than the actual number of students that made comments about positive changes in attitudes. The student quotations selected as attitude changes may be found under the category "Effects on Attitudes" in Appendix A. Some representative examples are given here.

J.C.: "I have enjoyed science for the first time in a long time. I hope I can present science in the same way to kids in my classroom."

P.H.: "The time for questions and individual help is wonderful. I don't feel <u>uncomfortable</u> about asking for help and it's nice to know that the door is open for that help. . . Excellent!" (my emphasis)

M.C.: "They have a deep desire to want the student to understand and are very concerned if they don't. I must say again, it's not only the labs and lectures I so enjoy, it is the instructors themselves who have made science for me a <u>most enjoyable</u> and fun experience." (my emphasis)

C.S.: "Everyone is on a first name basis and I think this helps keep it informal and non-threatening." (my emphasis)

M.C.M.: "I have always had a bad attitude towards science. . .I was very nervous about taking this class . . .I knew it would be a struggle. . . Hands-on experience in the small-group have been very helpful in clearing up some of this confusion. I seemed to understand the concepts much better after seeing them actually happen."

INTERVIEWS (Appendix B): Many positive quotations related to the improvement in student attitude toward science and science teaching can be found in the interviews. Seventeen of the 22 students interviewed have quotations showing a positive change in attitude listed under the "Change in Attitudes" category in Appendix B. The intertwining of attitudes, knowledge and skills (refer to previous section's discussion) made it too difficult to extract clear statements on attitudes from the 5 interviewed students whose responses were not included in the attitudes category. A few examples from this category follow.

INT: "Would you recommend this course to someone with high anxiety towards science?" B.D.: "Yes." INT: "Why?" B.D.: "You wouldn't have anxiety anymore. A class you'd enjoy going to although I had a high anxiety to start out with. The atmosphere of the classroom is very positive, pro-learning, very helpful, very non-threatening, felt you wouldn't be ridiculed."

I.B.: "On the first day of class, I approached you and Tom and told you that I was really paranoid about taking this class. That went down because of your attitude. You love what you're doing and are constantly here helping all of us and that gave me alot of self-confidence. I feel that I can ask the same question 5 times. In other classes I had felt that I couldn't do that."

P.H.: "My anxiety towards science was fairly high before taking this class... Since this class, my attitude has improved, like to talk to friends about class. I am still a little nervous, not 100% confident, but my enjoyment level is more... I put off taking this class--didn't want to take science. Glad I did now. I really want to learn

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now. Class is meeting my expectations. Class atmosphere is relaxed--can enjoy oneself, not stuffy."

S.D.: "My anxiety has gone down since taking this class... I am not as afraid of science. I am enjoying this class, learning something I didn't know --I see I can do it. I have developed more confidence to learn science."

TRANSFER OF LEARNING/TEACHING SKILLS (Appendix C): Many quotations exhibiting a positive change in student attitude toward science and science teaching occur throughout this open-ended exercise. In the categories of "Good Role Model:..." and "Less Anxiety, More Enjoyment & Confidence in Teaching", 32 out of 54 students made clear expressions of positive changes in Attitudes. Recall the previous discussion on the problem of extracting specific quotes on attitudes when attitudes, knowledge and skills are intertwined. Therefore, a minimum of 32 students expressed positive attitude changes. Here are several examples:

M.C.: "This course has definitely changed my attitude and I must thank my instructor(s) once again for making it such a rewarding experience--for helping me to learn something that I didn't think I could do so well at, at the beginning of the term! It's nice to know I can now be a more confident teacher in the science field."

M.L.: "Science isn't going to be any fun unless the children in my classroom are effected by it. If they can't participate and see for themselves that what they are learning is actually true, what good is it? Science is for them too! They can be scientists and that it is nothing to be afraid of. If I can learn this way, they certainly can. And if it helped me and I enjoyed it, so can they enjoy it and gain understanding."

J.C.: "This class has changed my attitude toward teaching science to children. I feel competent that I could do almost a entire year of science lessons just from the material I learned in this class."

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A.L.: "My attitude toward science is much better now than it was 10 weeks ago. You made science fun again."

S.G.: "I was very intimidated and anxious about taking this course. I later became quite comfortable with the concepts and the labs. If I can make my science lessons as awakening, comfortable, and manipulative, I'll be a good Science teacher."

ANONYMOUS STUDENT EVALUATIONS: (numbers on quotes refer to order in Appendix D). Comments related to the reduction in anxiety and more enjoyment toward science and science teaching are found throughout the anonymous student evaluation. About 31 clear statements out of 41 returned forms can be found in the categories of "Good Role Model: ...", "Less Anxiety, More Enjoyment and Confidence in Teaching" and "Comparison With Other Classes: Science, Methods, Etc." in Appendix D. Although there were 54 students in this course, only 41 forms could be considered. Thirteen forms were either not returned or did not contain any written comments. Again filling out these forms was totally voluntary and occurred on the day of the students' final exam. There can be several reasons for not doing them--among them is the need to be on time for another exam. Several examples of anonymous quotes follow:

1) "Super class! One that I enjoyed more than any other science class I've had. I began this class dreading taking it. It was so much more enjoyable and I learned a tremendous amount of information about Physical Science and feel much more competent in teaching science."

10) "I enjoyed the lab class. It was interesting and educational. I also enjoyed the instructor. He looked as though he enjoyed what he was doing and conveyed a very positive attitude toward his students, helping us when we needed it. I'd recommend his class to others."

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1) "He conducted class with a warm and friendly atmosphere making students feel very comfortable--my high anxiety went from high to low because I was always assured with a positive attitude and that 'I could do it'. . . This science class was a very rewarding and enjoyable experience for me and the instructors made this possible."

2) "I actually liked the class. I am surprised. Thank you. I will feel more confident in teaching science. Now I want to take more science classes."

3) "I liked the friendliness of the lab instructors and the friends I was able to make in lab."

*4) "Excellent class-I feel I really got alot out of the class both personally and professionally."

COUNTER-EVIDENCE: Some possible disconfirming evidence might be indicated by the following student responses. Both statements occurred during interviews and may be found in Appendix B in the category "Change in Attitudes".

D.S.: "College biology was hard for me because it moved too fast--didn't want to tell them to slow down... since taking this class, my anxiety has gone down a little bit. Sometimes I feel lecture is too fast..."

P.L.: "My elementary teachers had a very bad attitude towards science and it effected my attitude. . . Since taking this class, I enjoy science more, but my anxiety is still high..."

The above two students still indicate a high degree of science anxiety. Although there is an indication at the time of these quotes that there has been some movement in the positive direction, readers may assume that these two students represent no significant decrease in science anxiety. These two students, along with perhaps a different student in the above attitude scales (Q-35), would then represent the only clear counter-examples out of 54 students. These possible three cases would not be enough to refu

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refute the stated assertion in the face of the overwhelming supporting evidence.

RELATING ATTITUDE ASSERTION # 1 WITH LITERATURE: Assertion # 1 has strong supporting data. In summary, the supporting data shows that:

1) Over 2/3 of the entering students reported anxiety toward learning physical science and over 1/2 of the students reported high anxiety toward science in general.

2) Student anxiety toward the learning and teaching of physical science decreased substantially during this course.

3) Students attributed their decrease in anxiety to:

   a) concrete, relevant learning experiences that produced an excitement of observing and manipulating the phenomena first-hand.

   b) instructors' attitudes and compassion that fostered a feeling of security so that they were able to ask naive questions without the fear of ridicule or punishment.

   c) the pace, content and design of the course that nutured friendship and trust among the memebers of the small lab groups and the lab instructors.

The following discussion of these findings draws on pertinent literature which emphasizes the important role that attitudes towards science learning and science teaching. The following excerpts from professional publications are consistent with the notion that many of the prospective elementary teachers entering this class show little interest in learning or teaching science. They also indicate that this negative attitude toward the learning and teaching of science is closely related to the prospective teachers' educational experiences including their science experiences in high school and college.

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An important factor in the course design was the influence of teacher expectations on student achievement. The staff's expectations of high levels of student achievement was successful in fostering higher expections in their students. They, the students, developed higher expectations for themselves as learners and teachers of science. It was then hoped that this role modeling of high expectations by the staff would then be used by these prospective teachers as a method for improving the achievement of their own future students.

The importance of high expectations throughout the educational environment is emphasized in School Learning Climate and Student Achievement (1980). The authors state:

> Teachers' expectations for students are closely tied to the expectations teachers hold for themselves. It is essential for teachers to have HIGH EXPECTATIONS FOR THEMSELVES as teachers and high expectations for students as learners (Lezotte, et al., p. 103).

The phrase "high expectations for themselves" is of particular importance as a proper attitude on at least two levels of educational practice. It is important for prospective elementary teachers to have high expectations for themselves as science teachers when teaching their students. It is, as shown in this research, equally important for their teacher training staff to use this principle of high expectations when teaching prospective elementary science teachers.

These high expectations provide the motivational basis for the prospective teachers to improve their science learn-

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ing and teaching skills. It is this motivation to improve that Yager (1986) has identified as the critical factor in producing effective science teachers.

The course design reflected the belief that the high expectations of the staff would also influence the beliefs of the prospective teachers as to the type of elementary science teaching they could perform. According to What are the Needs in Pre-College Science. . . Education? (1980), the teachers' beliefs are central to the type of teaching that occurs and therefore, the teacher's role is critical in instituting change in elementary science teaching. This quote emphasizes the importance of this belief.

> ... within any classroom the science taught and the way it was taught is dependent primarily on what the individual teacher believes, knows, and does. Numerous studies indicate that the type of instruction does affect the student learning and that the teacher is the most important instructional variable. The critical role of the teacher in instituting change is well documented (NSF Report, SE 80-9, p. 49).

In decreasing science anxiety and fostering high expectations, the course design decreased the related problems of poor confidence and little comfort with science teaching. Project Synthesis, Volume 3 edited by Harms and Yager (1981) describe the majority of elementary teacher as lacking in confidence and as being uncomfortable with science teaching methods. The project states:

> Many elementary teachers lack confidence in their knowledge of science concepts (Harms & Yager, p. 88).

> Many elementary teachers are not aware or comfortable with different methods of teaching science (Harms & Yager, p. 86).

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The course design increased their confidence in understanding science concepts by providing the students with concrete, relevant learning experiences. The hands-on, guided-discovery teaching methods experienced by the students as enjoyable, successful learning experiences made them very aware and comfortable with various methods of science teaching. The importance of the preservice teacher experiences including those which influence attitudes, such as the above, should not be underestimated. Project Synthesis, Volume 3 further emphasizes this when it states:

> The elementary teacher preservice program has a significant influence on preparing elementary teachers' ATTITUDE and knowledge (Harms & Yager, p. 24).

This preservice course significantly improved the students' attitudes toward the learning and teaching of science. With this type of specially designed science content course the limited and deficient elementary science experience as described below should become atypical. These results have shown that anxiety toward learning physical science can be decreased among prospective elementary teachers through this course instruction.

Project Synthesis, Volume 3 includes teacher interest as being an important part of this problem, when it states:

> The typical elementary science experience of most is at best very limited. Most often science is taught at end of the day, if there is time, by a teacher who has little INTEREST, experience, or training to teach science. (Harms & Yager, p. 73).

The staff's high expectations and other positive attitudes contributed to the positive changes in the students

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from the typical elementary teacher as described above. The prospective teachers' increased confidence, greater comfort and growing interest in science learning and teaching can only result in a better elementary science experience for our nations' children. The research data provided insight into how this special course decreased the prospective teachers' science anxiety and fostered their positive attitudes toward science learning and teaching. The related literature illustrated the importance of this result.

It should be emphasized that the students who experienced this specially designed course were typical elementary education majors. The research data verifies that upon entering the course they could be easily considered by professional educators as being within their description of the national norm of prospective elementary teachers. The decreased level of anxiety and increase in positive science attitudes towards learning and teaching science exhibited by the students was accomplished by a typical group of prospective elementary teachers. This fact dramatically supports the idea that most students can improve attitudes towards science learning and science teaching if provided with an experience of a science content course that treats the development of positive science attitudes as a major instructional goal. These results deserve close attention from the professional educators who for many years have voiced major concerns over the deficient attitudes towards science teaching exhibited by many prospective and practicing elementary teachers.

ATTITUDE ASSERTION #2: The laboratory experience provided during this course was an extremely important contributor in decreasing most students' anxiety toward the learning and teaching of science.

SUPPORT: There is no statistical data from the surveys that directly relate the type of laboratory experience to the decrease in the students' anxiety toward science and science teaching. The statistical surveys did not attempt to measure this relationship. However, extensive evidence of this relationship exist throughout the ethnographic data.

The precautions for Ethnographic Methods discussed in the previous assertion also applies to the following Ethnographic Methods. The number given as the number of students who gave clear examples in each method compared to the total number of students who could have given a clear example should be treated as the minimum number of examples for each Ethnographic Method.

<u>SPECIAL RESEARCH EXERCISE</u> (Appendix A): Thirty-four students out of 54 gave clear statements about the benefits of the laboratory experience. Here are some examples:

B.D.: "The laboratory experience has the major benefit of keeping me in class. If all we had were lecture, textbook and problem sets, I probably would have forfeited my tuition expense and stopped coming. The only attitude I would have gained concerning science is a renewed fear and dislike. . . I have come a long way toward opening my mind enough to explore science. (My lab instructor's) very personal approach in lab has been <u>extremely</u> helpful and encouraging. His sense of humor, straightforwardness and consideration of students encourages the asking of questions. . . He makes learning non-threatening."

M.A.: "I really like all the attention he gives us. He doesn't just sit there while we do the lab. He actually 'does it' along with us."

J.C.: "There is always a chance for questions and I feel like a person not a number which is a rare thing in such a large university. The lab instructors really seem to care if we are understanding and picking up the concepts. I have enjoyed science for the first time in a long time. I hope I can present science in the same way to kids in my classroom."

P.H.: "Small group lab has definitely improved my enjoyment of science. The atmosphere is relaxed, not tense, and informal--allowing for alot of open discussion and participation. I don't feel inhibited anymore to take guesses or make conclusions about what is happening in lab, because I know and feel it's okay to do so and I won't be penalized for my wrong guesses."

K.D.,: "The small group lab has also taken much of the pressure off and I have found I am beginning to enjoy it. Before I came into the class I was very scared! I knew nothing about physical science and I just knew I wasn't going to understand anything. But to my pleasant surprise, I am finding that is not true and I know half of it rests on the fact of how the class is conducted."

J.P.: "I want to stress that although I do not typically enjoy a 'lab situation', I am grateful for this one. It made the concepts 'real' and understandable. . . It has made me much more open to science and much more accepting to teaching it and really becoming <u>involved</u> in it. I do want science to have an important place in my classroom--these lab activities have helped form that desire."

<u>INTERVIEWS</u> (Appendix B): Eighteen students out of 22 gave clear statements about laboratory benefits regarding their learning experience. Here are some examples:

I.B.: "My past experience in science was negative because I was frustrated with books which were used and lack of hands-on experience. This class stresses learning first and then grades. .... and .... students to learn and enjoy. Positive outlook. I actually feel confident in teaching science now."

M.S.: "The lab is especially helpful. I'm enjoying science for the first time. . . I look forward to lab. I am a little shy--feel comfortable with a small group.

....'s enthusiastic and makes it enjoyable. I am able to ask questions."

M.C.: "The atmosphere of class improved my understanding and attitude. I looked forward to lab. Always someone to help. Enjoyed the atmosphere--certain level of comfort-ableness."

M.A.:"Labs. I couldn't just get it from lecture. Small labs and extra help... "The lab is especially helpful. I'm enjoying science for the first time... I look forward to lab. I am a little shy--feel comfortable with a small group. (Lab instructor is) enthusiastic and makes it enjoyable. I am able to ask questions."

<u>TRANSFER OF LEARNING/TEACHING SKILLS</u> (Appendix C): Thirty-five out of 54 students indicated clearly benefits regarding the laboratory experience. Here are some examples:

S.G.: "I was very intimidated and anxious about taking this course. I later became quite comfortable with the concepts and the labs. If I can make my science lessons as awakening, comfortable, and manipulative, I'll be a good Science teacher."

M.L.: "And if it (lab) helped me and I enjoyed it, so can they (my students) enjoy it and gain understanding. I can teach this stuff because I can understand it and demonstrate it and help the children to demonstrate it, too."
M.S.: "The hands-on, small group lab experience has given me a more positive attitude towards science and the teaching of it."

C.H.: "I have a more positive and confident attitude about teaching science and a lot of it can be attributed to the lab experience. Because my attitude towards science has improved, I think I have a better ideas of the kinds of things that might motivate students and en-courage them to experiment and learn."

B.DEL.: "This is my first term back in school in about 13 years. I took physical science because I was concerned about it and wanted to get it over with quickly. My goal is to become an elementary teacher. To date, I have not declared my minors and had not even considered science as a possibility. I have enjoyed the hands-on and small group experiences so thoroughly that I am considering science as one of those minors.

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ANONYMOUS STUDENT EVALUATIONS: (numbers on quotes refer to the order of responses in Appendix D): Thirty-one out of 41 students volunteered clear statements about laboratory benefits. Here are some examples:

2) "The lab was very helpful to me. I have never enjoyed any science class before. The science class was set up in a way in which students could understand the material. I actually liked the class."

10) "I enjoyed the lab class. It was interesting and educational. I also enjoyed the instructor. He looked as though he enjoyed what he was doing and conveyed a very positive attitude toward his students, helping us when we needed it. I'd recommend his class to others."

3) "I liked the friendliness of the lab instructors and the friends I was able to make in lab."

COUNTER-EVIDENCE: Some possible disconfirming evidence could be indicated by the following student responses. The first statement is from "Suggestions for Improvement" section in Appendix A and the second statement is from the "Suggestions for Improvement" in Appendix D.

P.P.: " I think a little more time is needed to discuss some of the labs as a whole class ... like the color lab."

2) "I feel you should try to circulate around the room more during lab. You seemed to stick mostly to one group in helping them and in asking them questions. This bothered me a bit. Otherwise, everything was okay."

The above two students seem to indicate some anxiety in relation to their laboratory experience. However, their criticisms seem to relate to a certain aspect of lab and not the whole laboratory experience. For the sake of argument, let's assume that the two students suffered no decrease in their anxiety throughout their laboratory experience. These two students would then represent two counter-

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examples out of 54 students. These two cases would not be enough to disconfirm the stated assertion in the face of a much larger amount of supporting evidence.

RELATING ATTITUDE ASSERTIION # 2 WITH LITERATURE:

Assertion # 2 has strong supporting data. In summary, supporting data show that the students decreased their anxiety toward learning science and increased their confidence in their ability to teach science. The students attributed their decreased anxiety and increased confidence to:

1) the hands-on lab experience
2) the non-threatening, small group teaching strategy
3) the positive science teaching role models provided by the lab instructors

The following discussion of these findings draws on pertinent literature which emphasizes that many prospective elementary teachers need and would benefit from a hands-on laboratory science experience. These excerpts suggest that the lack of proper science learning experiences in prospective elementary teachers translate into deficient elementary science teaching. Also included are some excerpts which propose how proper hands-on laboratory experiences could help remedy these deficiencies.

An important factor in the course design was the laboratory teaching techniques which included concrete, hands-on, small group learning experiences. The importance of this laboratory approach is described in Teachers Make a Difference by Good, Biddle & Brophy. They conclude:

> The authors note that the more SUCCESSFUL teachers .... spoke to the class as a whole in order to provide structure and give general directions, but MOST of their

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> actual INSTRUCTION was given in SMALL GROUPS or to individuals (Good,... p. 70). (my emphasis)

The lab instructors' use of small groups as a teaching model allowed the prospective teachers to experience successful learning in spite of students high science anxiety and therefore increase their desire to use this approach in their own elementary science teaching. This approach should decrease the number of poor elementary science experiences as described in Project Synthesis, Volume 3 (1981). Harms & Yager state that:

> The TYPICAL elementary science experience .... will consist if reading and memorizing some science facts related to a concept too abstract to be well understood by the student ....(Harms & Yager, p. 73). (my emphasis)

Harms & Yager follow this account with a description of what a science classroom should be. They believe that:

> ... the classroom SHOULD be the place to excite students' curiosity, build interest in the world and themselves, and provide them with opportunities to PRACTICE the methods of science (Harms & Yager, p. 75). (my emphasis)

The student descriptions of the laboratory experience exciting their curiosity and providing opportunities for first-hand learning experiences are common. The physical science staff believed that the basis of the prospective teachers teaching with methods that produce curiosity and science learning skills, as described above, is for them to have experienced their value in their own learning experience. This would decrease the occurrence of the typical elementary science experience as described previously. This lack of proper learning experiences is emphasized as the basis of poor elementary science teaching by the National Science Board. In Educating Americans for the 21st Century (1983), the Board reports the following:

> The Commission finds that our students spend too little time in the course of their schooling in the study of academic subjects ... and devote too little time to 'HANDS-ON' EXPERIENCES (NSB Report, p. 28).(my emphasis)

The Board offers a partial solution to this problem when they recommend the following:

> Elementary... science teachers should be REQUIRED to have ...college courses in ... the PHYSICAL sciences (NSB Report, p. 32). (my emphasis)

A National Science Foundation Report, What Are The Needs in Pre-College Science ... Education (1981) perceives the same lack of science content and learning skills in elementary teaching. However, they are more specific when they state that the science courses should be a part of teacher training programs and that the science experience should include the laboratory-inquiry approach. The following excerpts pertain to this view:

> Many state science supervisors and elementary school principals considered 'INADEQUATE teacher preparation in science ... to be a SERIOUS problem in their schools (What are ..., p. 94). (my emphasis)

> Five benefits of laboratory-inquiry approach are listed: 1) Lab work provides PERSONAL experiences for students. 2) Lab experiences provide information that is ALMOST IMPOSSIBLE to convey in a textbook. 3) The lab requires ACTIVITY of students in a time when many young people lead increasingly passive lives. 4) Scientific observations and experiments frequently show limitations and uncertainities of scientific PROCEDURES. 5) Most students find that lab work is FUN (What are ..., p. 95). (my emphasis)

The staff's emphasis on concrete first-hand small group lab experiences contributed to the positive changes in the

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students toward the learning and teaching of science. Prospective teachers attributed the laboratory experience as being extremely important in providing them with a greater interest in learning science and with a greater confidence in teaching science. This can only result in better elementary science experience for our nation's children. The related literature demonstrated the importance of the laboratory experience.

The above descriptions and concerns from professional educators are consistent with the needs described by the students that were remedied in part by the hands-on laboratory experience. It has previously been established that the student population research could be identified as typical for prospective elementary teachers. Therefore, the dramatic laboratory benefits expressed by the students as improving their science attitudes and learning skills simultaneously was accomplished by a group of typical elementary education majors. This fact strongly supports the above assertion that the students laboratory experience was important in decreasing their anxiety towards the learning and teaching of science. These results close attention from professional educators who have voiced major concerns over deficient science attitudes and laboratory skills exhibited by many prospective and practicing elementary teachers and who have voiced concerns about modifying teacher training programs with courses that provided the basis for improving elementary science teaching.

Knowledge Assertions.

KNOWLEDGE ASSERTION #1: Many students increased their understanding of wave phenomena after completing this course.

SUPPORT: Support for this assertion is provided by both statistical and ethnographic data.

1. OPEN-ENDED WAVE QUESTIONNAIRE (Table 4): Scientific Definitions and Explanations. Each scale below follows the coding procedure explained in Chapter 3. The percentage of responses in the left column are "clearly correct". The second column is "inferred correct". The third column is "no response". The fourth column is "inferred incorrect". The far right column is "clearly incorrect". All three of the following questions show that a higher percentage of student responses are occurring toward the more correct end of the scale in the posttest as compared to the pretest thereby giving support to the assertion.

Q-1: WHAT IS A WAVE?

	clearly correct	inferred correct	no response	inferred incorrect	clearly incorrect
pretest	1.7	3.4	10.3	13.8	70.8
posttest	48.2	37.5	10.7	1.8	1.8

Combining the correct and inferred responses on the pretest, Q-1 accounts for 5.1% of the students. On the posttest, the correct responses and inferred correct responses has increased to 85.7% of the students.

Q-3: WHAT CAN WAVES DO?(E.G. DESCRIBE SOME WAVE PROPERTIES)

pretest	12.1	6.9	8.6	17.2	55.2
posttest	75.0	14.3	7.1	3.6	0.0

The answers for Q-3 and Q-4 did not require the same degree of scientific precision to be considered correct.

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Therefore, the percentage gain in correct responses is not as great, but still is impressive. Combining correct and inferred correct responses in Q-3 involves 19% of the students in the pretest. On the posttest, the percentage has increased to 89.3%. In Q-4, 36.2% of the students gave correct responses on the pretest whereas 92.9% gave correct responses on the posttest.

Q-4: WHAT COMMON EXPERIENCES DO YOU THINK YOU UNDERSTAND IN TERMS OF WAVES? EXPLAIN.

	clearly correct	inferred	no response	inferred	clearly incorrect
pretest	29.3	6.9	38.0	13.8	12.0
posttest	76.8	16.1	7.1	0.0	0.0

2. WAVE DEFINITIONS QUESTIONNAIRE (Table 5)

The same scoring procedure described above for the open -ended questionnaire was used for this questionnaire.

Dramatic Support: The following 5 questions show a dramatic increase of at least 70% of the student responses as being clearly correct (the first column) from the pretest to the posttest.

Q-13: DIFFRACTION	clearly correct	inferred	no response	inferred	clearly incorrect
pretest	0.0	3.4	72.5	6.9	17.2
posttest	80.4	5.4	8.9	3.5	1.8
Q-10: RESONANCE					
pretest	0.0	0.0	72.4	0.0	27.6
posttest	80.4	14.3	1.8	3.5	0.0
Q-9a: INTERFERENCE: CONSTRUCTIVE					
pretest	6.9	10.3	39.7	6.9	36.2
posttest	89.3	8.9	0.0	0.0	1.8

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Q-7a: LONGITUDINAL WAVE: COMPRESSION					
pretest	8.6	13.8	46.6	1.7	29.3
posttest	94.6	1.8	1.8	0.0	1.8
Q-5a: AMPLITUDE					
pretest	8.6	5.2	31.0	10.4	44.8
posttest	82.1	5.4	3.6	1.8	7.1

Strong Support: Q-11 shows an increase of almost 75% in the correct and inferred correct responses (first two columns). Q-4a and 4b do not show as large an increase due to the common usage of the terms, but the clearly correct responses (first column) involved 100% of the students on the posttest.

Q-11: BEATS	clearly correct	inferred	no response	inferred	clearly incorrect
pretest	0.0	1.7	58.6	0.0	39.7
posttest	55.4	19.7	12.5	7.1	5.3
Q-4a: CREST					
pretest	77.6	1.7	8.7	3.4	8.6
posttest	100.0	0.0	0.0	0.0	0.0
Q-4b: TROUGH					
pretest	72.4	3.4	15.6	1.7	6.9
posttest	100.0	0.0	0.0	0.0	0.0

3. <u>Ethnographic Data</u>

The following student quotations from the four Ethnographic data sources employed in this research compare well with the above knowledge questionnaires by illustrating a poor understanding of wave phenomena upon entering this course. They also indicate a shift toward greater understanding of wave phenomena on the part of the students as a result of this course thus supporting the above assertion. Only a few representative examples from each ethnographic method will be give here as evidence of support. The readers interested in greater detail may read the numerous supportive responses in the Appendix that is indicated for each method.

A note of caution is appropriate before looking at the ethnographic data. The ethnographic data did not attempt to measure direct retention of knowledge. Statements by the students consist of their perceptions of knowledge retention and therefore supply indirect support for greater understanding of wave phenonemena.

SPECIAL RESEARCH EXERCISE (APPENDIX A)

M.L., 4-29-85: "The most simple understanding of waves that I thought would help elementary children (and me too!) is the demonstration with the slinky. I saw clear as day what a transverse and longitudinal wave were."

P.P., 7-8-85: "The ripple tank was also fun because we could manipulate various aspects of it and see the different effects caused by our manipulation. It demonstrated and helped me understand the phenomena of diffraction, refraction and reflection, and the effects of constructive and destructive interference."

B.D., 7-8-85: "Until I actually shook the slinky I didn't really get (understand) wave motion."

INTERVIEWS (APPENDIX B)

I.B., 5-1-85
"The lab and hands on experiments made science alot easier to understand... The lab experience is an 'aha' experience for me. When I can't interpret diagrams in the text, I am able to see it in lab, e.g., ripple tank."

M.C., 5-1-85:
"The hands-on, visual, small group gives you a whole new understanding about waves and sound. I had very little knowledge before... You couldn't visualize sound waves and how they refract and diffract and interfere if it weren't for the ripple tank. I could see the words diffraction and refraction come alive when we did ripple tank. What I liked about lab was that it allowed me to do it so I truly comprehended what I read about..."

TRANSFER OF LEARNING/TEACHING SKILLS (Appendix C)

M.S., 6-6-85: "Many times I didn't understand the concepts being given, until I actually created it myself."

L.B.,6-6-85: "I've realized how much easier and quickly ideas and concepts are grasped when you can manipulate the factors yourself and as many times as you need to to see them."

S.G., 7-22-85: "I may have still been a little confused after observing the wave pattern in the ripple tank, but I knew more than if I had only read about the pattern or been told about it. Seeing is believing and I think this is especially true for science and for children."

S.V., 7-22-85: "The small lab groups are a very definite advantage to learning and has increased my understanding of readings and lectures in this class."

M.M. 7-22-85: "Before I always considered myself too dumb to ever understand anything scientific. This class is helping me to see that this is definitely not the case. I think alot of it has to do with the small group lab experiences."

ANONYMOUS STUDENT EVALUATIONS (Appendix D)

4) "The lab instructors were very concerned that we understood all of the material. There was alot of work to do, but it all helped me to understand the material whether I wanted to or not."

3) "This is one of the (few) classes I have taken at M.S.U. where I feel I have learned a great deal. I believe alot of it had to do with the lab. I was able to have a hands-on experience with what I was reading and learning in lecture."

1) "The class was very enjoyable and I found it an easier way to learn."

*4) "Excellent class--I feel I really got alot out of the class both personally and professionally."

2) "The lab was very helpful to me. I have never enjoyed any science class before. The science class was set up in a way in which students could understand the material. I actually liked the class."

The literature related to Knowledge Assertion # 1 is also closely related to Knowledge Assertion # 2. An appropriate discussion of the literature will occur after the discussion of Knowledge Assertion # 2.

KNOWLEDGE ASSERTION #2: Many students gained an understanding of wave phenomena that was beyond the memorization level of learning complexity and achieved a knowledge retention period that was greater than short-term recall.

Two types of data pertaining to this assertion are incorporated below. First are data that show that students acquired knowledge that is of a higher level than simple recall of factual information. This is headed "Beyond Memorization". Second are data that show that students retained knowledge for a period of time after their unit tests. This is headed "Beyond Short-Term Recall".

Evidence pertaining to: BEYOND MEMORIZATION

Several types of knowledge questionnaires were used to measure the students' depth of understanding. The questionnaires at times required that the students answer open-ended explanation questions, prepare their own sketches with their own explanations, and transfer the principles they had learned to explain novel situations. Here are some examples of how the questionnaires measured for knowledge that was understood beyond memorization.

1. OPEN-ENDED WAVE QUESTIONS: (Table 4) Scientific Explanations.

Each scale below follows the coding procedure explained in Chapter 3. The percentage of responses in the left column are "clearly correct". The second column is "inferred correct". The third column is "no response". The fourth column is "inferred incorrect". The far right column is

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"clearly incorrect". Both of the following questions show that a higher percentage of student responses are occurring toward the more correct end of the scale in the posttest as compared to the pretest thereby giving support to the assertion.

Q-3: WHAT CAN WAVES DO?(E.G. DESCRIBE SOME WAVE PROPERTIES)

pretest	12.1	6.9	8.6	17.2	55.2
posttest	75.0	14.3	7.1	3.6	0.0

Q-4: WHAT COMMON EXPERIENCES DO YOU THINK YOU UNDERSTAND IN TERMS OF WAVES? EXPLAIN.

pretest	29.3	6.9	38.0	13.8	12.0
posttest	76.8	16.1	7.1	0.0	0.0

The answers for Q-3 and Q-4 did not require a specific answer that could be memorized nor did they have a clue in their questions limiting the range of right answers. The open-ended questions just asked the students to tell what they knew about wave phenomena, thereby requiring a level of understanding beyond memorizing. Combining correct and inferred correct responses in Q-3 involves 19% of the students in the pretest. On the posttest, the percentage has increased to 89.3%. In Q-4 pretest, correct and inferred correct responses were 36.2% while in the posttest, the responses were 92.9%

2. SKETCH, LABEL & EXPLAIN WAVE PATTERNS (Table 6).

The following 4 questions show a level of understanding beyond memorization by requiring the students to produce a sketch of a specific wave phenomena and then to explain the sketch. There is not just one sketch that could be considered as the right answer, but a number of ways the

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students can sketch the phenomena or provide an explanation. Looking at only the correct responses (first column), the percentage of student responses have increased from 44.7% on the pretest to 71.8% on the posttest over the 4 questions. Correct answers required that the student be able to apply principles to situations that required sketching or explaining.

RIPPLE TANK: SKETCH & EXPLAIN

Q-3a: COMPARE DIFFRACTION: DIFFERENT SIZE OPENINGS

	clearly correct	inferred	no response	inferred	clearly incorrect
pretest	1.7	0.0	81.0	5.2	12.1
posttest	67.9	8.9	10.7	10.7	1.8

Q-3b: SKETCH INTERFERENCE: TWO POINT SOURCES

pretest	0.0	1.7	69.0	1.7	27.6
posttest	44.7	32.1	12.5	8.9	1.8

Q-3c: REFRACTION: DEEP TO SHALLOW WATER

pretest	0.0	5.2	72.4	0.0	22.4
posttest	64.3	14.3	10.7	8.9	1.8

GIVE BRIEF EXPLANATION:

Q-4a: HEARING A SOUND AROUND THE CORNER OF A HALLWAY

pretest	8.6	24.1	19.1	10.3	37.9
posttest	80.4	14.2	3.6	1.8	0.0

3. WAVE KNOWLEDGE TRANSFER Questionnaire (Table 8).

The following 3 questions required that the students understood certain wave principles then apply those principles to certain novel situations that were not covered in the course. Looking at only the correct responses (first columns), the percentage of student responses ranged from 36.5% to 100%. A note of caution is appropriate for Q-4d. Although some significant transfer of knowledge and there-

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fore support for this assertion occurred, Q-4d may not exhibit complete transfer of knowledge as defined above. First, the concept of heat transfer by radiation was used in the course. Secondly, certain "heat wave" terms could have common usage by the students without a higher complexity of understanding.

Q-4b: LIGHT

	clearly correct	inferred	no response	inferred	clearly incorrect
pretest	0.0	0.0	54.3	8.6	37.1
TRANSFER	41.9	38.7	0.0	12.9	6.5

Q-4c: ELECTRICITY

pretest	0.0	0.0	60.0	2.9	37.1
TRANSFER	36.5	29.0	8.7	6.5	19.3

Q-4d: HEAT

pretest	5.7	5.7	37.1	14.4	37.1
TRANSFER	100.0	0.0	0.0	0.0	0.0

Support for: BEYOND SHORT-TERM RECALL

The questionnaires at times required that the students answer questions 8 weeks after the learning experiences related to that knowledge. They also at times required that the students answer knowledge-transfer questions that involved applying principles that were experienced at different times, some as long as 8 weeks prior to the questionnaires. Here are some examples of these student responses.

1. SPRING TERM EIGHT-WEEK FOLLOW-UP (Table 7)

Each scale below follows the coding procedure explained in Chapter 3. The percentage of responses in the left column are "clearly correct". The second column is "inferred correct". The third column is "no response". The fourth

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column is "inferred incorrect". The far right column is "clearly incorrect". The following questions show that a high percentage of student responses are remain-ing at the "clearly correct" end of the scale in the 8-week Follow-up, thereby giving support to the assertion that many students achieved a knowledge retention period that was greater than short-term recall.

Q-2c: AMPLITUDE

	clearly correct	inferred	no response	inferred	clearly incorrect
pretest	20.0	0.0	22.9	5.7	51.4
posttest	93.9	0.0	6.1	0.0	0.0
FOLLOW-UP	87.0	0.0	3.2	3.3	6.5

RIPPLE TANK: SKETCH & EXPLAIN
Q-3a: COMPARE DIFFRACTION: DIFFERENT SIZE OPENINGS

pretest	2.9	0.0	85.7	2.9	8.6
posttest	60.6	12.1	12.2	12.1	3.0
FOLLOW-UP	61.3	16.1	6.5	12.9	3.2

Q-3b: SKETCH INTERFERENCE: TWO POINT SOURCES

pretest	0.0	0.0	82.9	0.0	17.1
posttest	42.4	33.3	15.2	6.1	3.0
FOLLOW-UP	32.3	48.2	3.3	6.5	9.7

Q-3c: REFRACTION: DEEP TO SHALLOW WATER

pretest	0.0	2.9	80.0	0.0	17.1
posttest	63.3	18.2	12.5	3.0	3.0
FOLLOW-UP	58.0	12.9	6.5	12.9	9.7

GIVE BRIEF EXPLANATION:
Q-4a: HEARING A SOUND AROUND THE CORNER OF A HALLWAY

pretest	14.3	8.6	22.9	11.4	42.8
posttest	75.8	18.2	3.0	3.0	0.0
FOLLOW-UP	71.0	19.3	0.0	9.7	0.0

2. WAVE KNOWLEDGE TRANSFER Questionnaire (Table 8)

The following three questions required that the students apply certain wave phenomena principles that they experienced at different times, some as long ago as 8 weeks prior to the questionnaire. Looking at the "clearly correct" responses (first column), the student responses indi-

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cate that many students had retained knowledge of these principles beyond short-term recall. Although the higher level of thinking skills were necessary to answer the Transfer questions and therefore could have interfered with "long-term recall", it was also essential that the students retain knowledge of the principles beyond short-term recall in order to achieve a "clearly correct" response. This evidence adds support to the assertion that the students retained some knowledge beyond short-term recall.

Q-4b: LIGHT					
pretest	0.0	0.0	54.3	8.6	37.1
TRANSFER	41.9	38.7	0.0	12.9	6.5
Q-4c: ELECTRICITY					
pretest	0.0	0.0	60.0	2.9	37.1
TRANSFER	36.5	29.0	8.7	6.5	19.3
Q-4d: HEAT					
pretest	5.7	5.7	37.1	14.4	37.1
TRANSFER	100.0	0.0	0.0	0.0	0.0

3. Ethnographic Data

The following student quotations from the four Ethnographic Methods employed in this research compare well with the knowledge questionnaires by supporting the assertion that the students gained a level of understanding beyond memorization and retained this knowledge beyond short-term recall. A few examples from each ethnographic data source will be given here as evidence of this support. The reader is encouraged to read the numerous supportive responses in Appendicies A-D.

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A note of caution is appropriate before looking at the ethnographic data. The ethnographic data did not attempt to measure direct retention of knowledge. Statements by the students are indirect indications of knowledge retention and therefore supply indirect but important support for the assertion that the students understood the knowledge beyond memorization and retained that knowledge beyond short-term recall.

SPECIAL RESEARCH EXERCISE (APPENDIX A):

T.R., 4-29-85: "Before the laboratory dealing with light I never considered light as being a wave, but I found out some fascinating facts about light. . .why shadows form. During this lab your hands were actually doing the work to form shadows. The lab allowed me to answer questions related to everyday life."

M.L., 4-29-85: "Lab not only showed me the basic concept of longitudinal and transverse waves, but it also showed me many important characteristics of waves that I'm sure will help me explain alot more things in everyday situations and class!"
M.C., 4-29-85: "Also that waves bend--this could be seen in the ripple tank--so now I can actually see how sound waves bend when my voice sounds hit a wall,etc.)

S.B., 7-8-85: "When you have to create the situation yourself, it means alot more and sticks with you a lot longer. Doing helps you really remember it and not just memorize it like you would be doing with just a lecture. Lectures alone aren't as applicable."

B.DEL., 7-8-85: "The wave tanks were excellent for visualizing wave phenomena (diffraction, refraction, reflection, and interference). . . This past 4th of July weekend I spent at a small lake near Lake Michigan. My family learned quite alot about wave phenomena."
B.DEL, 7-8-85: "I was very interested in the section on far and near-sightedness--these are terms everyone uses, but few can actually explain. . . rainbows were similarly interesting. I have already enlightened my wife in this regard and she was very impressed now she thinks I'm smart!"

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S.S., 7-8-85: "I feel that these labs are very beneficial . . . The waves are a phenomena I knew about and enjoyed (I love spending time watching waves and water flow), but getting the hands on experience of manipulating . . you gain a new insight into understanding what is really happening."

INTERVIEWS (APPENDIX B):

M.A., 4-29-85:
(RE: LABS):"Reading isn't enough... Labs give me a clear idea in my mind. From ripple tank experiment in lab, I know what it looks like in my mind. It helps me retain it--from having the visual experience... I really like this aspect."

S.F.,, 5-6-85:
INT: "Have you been able to relate class to outside experience?"
S.F.: "Constantly. The first two weeks of class when I was reading about waves, it made it seem like everything in the world is somehow related to waves. So anything that happened I would find myself talking about that or joking about it. My friend is really into science and understands alot more about it."

I.B., 5-1-85:
"I am amazed by the things I learn in class which I can relate to outside experiences such as blue skies and red sunsets, diffraction of waves on lakes. I didn't think about these things before.

B.Del., 7-24-85:
INT: "Do you see the relevance of learning waves to everyday life?"
B.D.: "Mainly light--I think about all aspects of it. Describing how black absorbs. It's what you're not seeing--that really struck me."

K.D., 7-9-85:
INT: "Do you think you would have really understood diffraction without doing the lab?"

K.D.: "No. I mean I would have known the definition of diffraction, but I really wouldn't have understood how the waves were diffracted as they came through the slits."

P.L., 7-22-85:
INT: "Do you ever relate waves to everyday life?"
P.L.: "Yes, the Doppler effect, when cars pass me; my stereo, how sound travels around corners; sunsets."

L.S., 7-22-85:
INT: "Can you relate waves to everyday experiences?"

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L.S.: "I'm driving my family crazy with examples--blowing on beer bottles--this is resonance!!"

TRANSFER OF LEARNING/TEACHING SKILLS (APPENDIX C):

M.C., 6-6-85: "The laboratory experience allowed me to become a scientist--I had to observe, predict and apply my knowledge."

M.L., 6-6-85: "The hands-on, small group laboratory is a must. You remember what you did longer because you yourself proved a theory! What lecture didn't cover, or help me understand, the lab did."

F.R., 6-6-85: "My hands-on experiences in the small groups has given me more reason to believe that students learn better with first-hand experiences. When you are able to work out a problem by actually working with it first-hand you receive more and you are more likely to remember it. Just hearing how an object works as in lecture isn't as fulfilling as figuring out how it works on your own."

M.E., 6-6-85: "These labs have shown me, and taught me that science isn't really as difficult as it seems at first. By doing these experiments and lab problems, it helps me greatly, because by doing these things I learn what i"m doing right and/or wrong, I can go back and do the experiments again and see where I went wrong and then I can correct it and learn it right."

L.E., 7-22-85: "I have always liked to work in groups so you can discuss your answers and express your logic. It helps to defend your understanding thus many misconceptions can be caught in the early stages and not get work into final understanding of the concept. I think children also need to have their predictions tested promptly so they get immediate feedback, thus small groups accomplish this."

ANONYMOUS STUDENT EVALUATIONS (APPENDIX D):

7) "I feel this is one course which will benefit me in my student teaching overseas and in my future teaching in the elementary classroom."

4) "I liked the chance to be able to do the experiments in lab to enhance my understanding of each topic we covered. You did a very good job! Thank you!"

3) "I was able to have a hands-on experience with what I was reading and learning in lecture. It made a great deal of difference in my understanding of the material."

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7) "I had . . . as an instructor and thought he was exceptional. This has been my favorite class at M.S.U. and I feel as though I've learned alot!"

10) "This was a very good class and very interesting because I learned so many new things--that I always 'thought' I knew."

COUNTER-EVIDENCE FOR KNOWLEDGE ASSERTIONS # 1 AND # 2:

Some possible disconfirming evidence might be indicated by the following student responses. The first statement is found in Appendix A. The next two statements occurred during the Interviews and are found in Appendix B. The last two statements were volunteered by students on the Anonymous Student Evaluation in Appendix D.

M.A.: "Lecture sometimes gets boring and hard to follow. Even when Dr. ... shows an experiment I still feel like I really don't understand."

D.S.: " ... Sometimes I feel lecture is too fast."

P.H.: "Although the demos in lecture are beneficial, sometimes the lectures are confusing--too much material."

1) "The only complaint is that some labs went very fast for me--not giving me time to absorb the concepts as I did them. However, I understand this was unavoidable in order to cover all necessary material."

*4) "At times, I feel that we were rushed--very rushed... Consequently, I don't think that lab was as valuable as it could have been. Obviously, with our 5 week time limit, some of the rushing could not have been avoided--I do understand that!"

The above statements do not directly weaken the knowledge assertions, but they do indicate some difficulty by the students in acquiring certain knowledge. These difficulties certainly do not mean that they did not succeed in acquiring some knowledge of wave phenomena beyond memorization and short-term recall. However, if we stretch this

Difficulty to infer that they didn't succeed in acquiring any knowledge, then these 5 cases would not be enough to refute the stated assertions in light of the dramatic supporting statistical and ethnographic evidence.

RELATING KNOWLEDGE ASSERTIONS # 1 AND # 2 WITH LITERATURE:

Both assertions have strong supporting data. In summary, the supporting data shows that:

1) Very few of the students understood wave phenomena before beginning this course. The few students who understood some aspects of waves could apply them to only a few, if any, situations.

2) A large majority of students increased their understanding of wave phenomena and their ability to apply this knowledge during this course.

3) Students attributed their increase in knowledge and its application to:

a) taking their first college physical science course that included a hands-on laboratory experience which emphasizes science learning skills.
b) the laboratory instructors' high concern for their understanding of concepts not memorizing them.
c) the lab instructors' use of analogies and guided-discovery approaches as techniques for teaching the science content.
d) the instructors' common references of how laboratory activities relate to the students daily life and potential teaching situations.
e) strong coordination between lecture and laboratory experiences presenting the same concepts.

The following discussion of these findings draws on pertinent literature which emphasizes the importance of prospecttive elementary teachers acquiring and benefiting from the understanding of scientific knowledge beyond memorization

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and short-term recall. These excerpts emphasize the importance of in-depth knowledge as a key to improving the science teaching of elementary teachers. They also include the concern that existing pre-service, in-service and other programs are deficient in supplying the needed scientific pedagogical knowledge in an efficient and effective program for prospective and practicing elementary teachers.

An important factor in the course design was the use of physical science content in the laboratory as the focal point of instruction. Few students understood wave phenomena which could be easily related to their daily lives. Students reported that hands-on laboratories offered learning experiences which promoted understanding of principles rather than memorizing facts. The students reported that the laboratory offered concrete experiences which were used for relating principles to daily environment and, therefore, promoting a longer retention of knowledge. Some students suggested that Physics' labs can offer an easier approach to learning science process skills in elementary science than Biological labs which ususally involve memorizing facts. Many students felt they were developing a new type of knowledge that was a synthesis of science content and teaching strategies. Those students for which this was their last class thought that this type of knowledge would have been particularly helpful in their student teaching.

Wilson & Shulman have recently written an article soon to be published in Exploring Teacher Thinking (1987). In thi

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this article, they discussed the belief that successful teachers must develop a special type of knowledge which is the product of transforming the knowledge they have gained from their course-work in content areas and their course-work in teacher education. They state that:

> ...novice teachers ... develop a new type of subject matter knowledge that is enriched and enhanced by other knowledge.... We call this knowledge pedagogical content knowledge (Wilson & Shulman, in press).

The difficulty of teachers developing this knowledge is demonstrated in part by the present design of most teacher training programs. Wilson and Shulman explain:

> ...seldom are explicit connections made between the course-work specific to teacher education and the course-work in content areas. Consequently, subject matter and pedagogy are treated as separate domains (Wilson & Shulman, in press).

This concern for the quality of teacher training programs is also expressed by Project Synthesis, Vollume 3. The report emphasizes:

> The elementary teacher preservice program has a significant influence on preparing elementary teachers' attitude and KNOWLEDGE (Harms & Yager, p. 24). (my emphasis)

However, this report does not emphasize the need for "pedagogical content knowledge" as Wilson & Shulman do. It believes the major reason for the ineffectiveness of elementary science teaching is the fact that the teachers do not take enough science content courses. Educating Americans for the 21st Century (1983) supports this belief when it states:

> ...our students spend too little time in the course of their schooling in the study of ACADEMIC subjects (NSB Report, p. 23).

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> Elementary ... science teachers should be required to have ...college courses in ...the PHYSICAL SCIENCES (NSB Report, p. 32)

This course design provided with the academic subject of physical science. A major emphasis of the course was learning science content. Students did acquire an understanding of wave phenomena beyond memorization and retained for a period of time longer than short-term recall. Wilson & Shulman (1987) agree that the "subject matter knowledge" is the focal point for providing the basis of all the processes involved in developing new types of knowledge. They, however provide this caution, when they state:

> ... while a personal understanding of the subject matter may be necessary, it is not a sufficient condition for being able to teach. Teachers must find ways to communicate to others (Wilson & Shulman, in press).

This course design also gave the students opportunities to discover ways to communicate their knowledge to others. The students expressed their appreciation for developing a new type of knowledge which was a combination of subject matter and teaching techniques. This was provided by the lab instructors' role model where the students were able to see first-hand the techniques involved in teaching science. According to many students, it was the type of class they were looking for--where the knowledge of science content and the knowledge of teaching is transformed into the knowledge of science teaching. The next section on Skills Assertions will develop this theme further.

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The above descriptions and concerns from professional educators are consistent with the needs and benefits described by the students who experienced this specially designed physical science course. It has previously been established that this student population could be identified as typical for prospective elementary teachers.

In the previous section, it was demonstrated that this specially designed course for prospective elementary teachers had a desirable effect on their attitudes. In this section, it is shown that their understanding of scientific principles was also increased and retained. These results support the above assertions that the students acquired scientific knowledge of wave phenomena beyond memorization and short-term recall and that part of this success was attributed to the development of a new type of knowledge not usually experienced in teacher training programs. They deserve attention from professional educators who have voiced concerns over deficient science knowledge and lack of proper science training exhibited by many prospective and practicing elementary teachers.

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Skills Assertions

SKILLS ASSERTION #1: Many students increased their use of science learning skills during this course.

SUPPORT: The students' development and use of science learning skills were not directly measured in any of the statistical surveys. However, they were measured indirectly through the skills survey. This survey measured the change in the students' appreciation of certain science learning and teaching skills and will be discussed later. The ethnographic methods provide an important insight in the students' own description of how they have increased their use of science learning skills through the laboratory experience. Highlighted throughout the following excerpts are words and phrases consistent with the development and use of science learning skills. These highlights include examples such as "hands-on", "do first hand", "think for ourselves", "performing", observing", "predicting", "manipulating" and "discussing".

A word of caution about the number of student re-sponses is appropriate. The students were not asked directly a question about the development of their science learning skills. The excerpts from the Ethnographic data in the Appendicies were extracted as clear examples of increased use of science learning skills. Many more examples are intertwined with Attitude and Knowledge excerpts. Therefore, any attempt to enumerate the number of students out of 54 who made statements about increasing their use of science learning skills would be difficult and perhaps misleading. Interested readers are encouraged to examine Appendicies A-D for more detailed data. Some examples from these Appendicies follow:

SPECIAL RESEARCH EXERCISE: (APPENDIX A)

K.D.: "I think by doing HANDS-ON experiments, I am more able to apply my new knowledge. Where perhaps if I had not been able to see and DO FIRST-HAND, I would still be at the stage of regurgitating vocabulary and state concepts."

B.D.: "The lab and recitation are helpful because it is a very friendly atmosphere. We can ask questions and not feel dumb by asking them. Also when we ask questions we don't just get the answer. We're asked to THINK FOR OURSELVES and guided to the the correct answer."

P.L.: "Laboratory experience was the most helpful in developing a 'scientific attitude' and learning science. The reason is because of hands-on experience and actually performing the experiments. The textbook was helpful when looking up definitions and when going more into detail, but I feel that I learned more when actually PERFORMING the experiments. I enjoyed the lecture alot. It helped me to learn the basics of what was being taught. However, more individual attention was given in lab where the experiment supplemented the lecture. DOING and SEEING or OBSERVING is better than just listening."

INTERVIEWS: (APPENDIX B)

M.C.: "What I liked about lab was that it allowed me to DO it so I truly comprehended what I read about. By OBSERVING, PREDICTING AND EXPERIMENTING, I realized that it's not as difficult as I thought it was."

TRANSFER OF LEARNING/TEACHING SKILLS: (APPENDIX C)

S.G.: "It is due to the positive influence of my small, HANDS-ON labs that I am a believer in teaching science the same way in my classroom. During the labs, I have PARTICIPATED, DISCUSSED, OBSERVED, PREDICTED."

M.C.: "I think the most important thing a student can do to learn is by 'DOING'--that's what we did in this science class. I will do the same with my students--I well make them 'do', become 'scientists' themselves--to teach them to THINK FOR THEMSELVES and solve problems after they have OBSERVED AND PREDICTED."

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L.B.: "I've realized how much easier and quickly ideas and concepts are grasped when you can MANIPULATE the factors yourself--as many times as you need to to see them."

ANONYMOUS STUDENT EVALUATIONS: (APPENDIX D)

"This is one of the (few classes) . . . where I feel I have learned a great deal. I believe alot of it had to do with the lab. I was able to have a HANDS-ON experience with what I was reading and learning in lecture."

COUNTER-EVIDENCE: The author could not find any clear statements or statements that clearly implied a decrease in the use of science learning skills by any students except for this anonymous statement from Appendix D.

*5) "I felt I would have got more out of this lab if you would have allowed more time for discovery."

Although "discovery" is not explicitly a science learning skill, it certainly should involve the use of some science learing skills and therefore, could indicate a derease in the use of some skills that had been developed by this student. If so, this one example would not be enough to refute the stated assertion in light of the impressive supporting evidence.

RELATING SKILLS ASSERTION # 1 WITH LITERATURE: Assertion #1 as strong supporting data. In summary, the supporting data shows that:

1) A large majority of the students have had few opportunities to develop their science learning skills. This means, in most cases, that their previous, if any, laboratory experiences were mostly cook-book activities involving the memorization of facts.

2) A large majority of students improved their use of science learning skills during this course.

3) Students attributed their increased use of science learning skills to the following:

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a) the hands-on laboratory experiences which allowed the students to observe, perform, predict and make conclusions about their activities.

b) the friendship and trust that was developed in the small-group lab environment so that the students felt secure about asking naieve questions about subject matter and lab procedures without the fear of ridicule or punishment

The following discussion of these findings draws on the pertinent literature which emphasizes the importance of developing the use of science learning skills. In the following excerpts, the words that are highlighted in captials are emphasizing Knowledge Processing Skills. They are related to the development and use of science learning skills and science teaching skills. These words are short and easily said, but only under close examination do they reveal the depth of thinking skills implied in their use. If prospective elementary teachers are to teach these learning and thinking skills--proper modes of scientific inquiry--to children, then they must have developed these skills in themselves. Apparently in the past this often has not been the case. The following literature excerpts exhibit that the development of these science learning skills in prospective teachers and thereby their students are important steps toward reaching the goals of science education.

Educating Americans for the 21st Century (1983) described some thinking skills a student should have developed after having completed his formal education:

> Students who have progressed through the Nation's school systems should be able to USE both the knowledge and products of science... in their thinking, their lives, and their work. They should be able to MAKE in-

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> formed choices regarding their own health and lifestyles based on evidence and reasonable personal preferences, after TAKING into consideration short-and long-term risks and benefits of different decisions. They should also be prepared TO MAKE similarly informed choices in the social and political arenas (NSB Report, p. 45).

In order to achieve the above goal, it has become increasingly apparent that science education needs to shift its goals and resources to developing generic thinking skills in all the nation's students. These skills are applicable to solution of daily problems regardless of the specific content of the problem. A important factor in the course design was to give the students an opportunity to develop some problem solving skills such as problem identification, prediction of consequences, manipulating variables, and the observing and testing of activities. This courses hands-on laboratory activities supplied some of these experiences.

Harms and Yager in Project Synthesis, Volume 3 (1981), report that developing these skills must be emphasized in young children who are naturally curious about the world if we hope to reach some level of thinking skills in all of our children. They state:

> During these early years, they FORM their basic attitudes, PATTERNS of thought, and MODES of behavior. It is, therefore, during these years that particular attention must be given to establishing the attitudes and MODES of inquiry that are associated with the scientific enterprise--its PROCESSES and content (Harms & Yager, p.73).

However, inadequate teaching has fostered negative attitudes towards science in young students. In Educating

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Amercians for the 21st Century (1983), the lack of adequately trained elementary teachers is cited as significant:

> The evidence that students entering primary school exhibit a natural curiosity about... the world around them, but are discouraged from consideration of serious study in these fields early in the elementary grades due to INADEQUATE teaching or lack of motivation (NSB Report, p. 42).

Again, Project Synthesis, Volume 3 indicates that the poor development of science learning skills in elementary teachers, when it emphasizes:

> A major reason for the ineffectiveness of many elementary teachers is the lack of proper training in the sciences (Harms & Yager, p. 24).

The staff's emphasis on concrete, first-hand, small-group, lab experiences contributed to the development and use of the students' science learning skills. Prospective teachers attributed the laboratory experience as being extremely important in providing them with the opportunity to use their science learning skills. They also attributed the lab instructors' attitudes as being important in providing them with a security so they could make mistakes without the fear of ridicule. The positive learning experience for the prospective teachers can only result in better elementary science teaching for our nation's children. The related literature demonstrated the importance of the prospecive teachers developing their own science learning skills.

The above descriptions and concerns from professional educators are consistent with needs and benefits described by the students who experienced this specially designed physical science course. It has previously been established

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ed that the researched student population could be identified as typical for prospective elementary teachers. Therefore, the development and improvement of the students' science learning skills from their first-hand laboratory experience was accomplished by a typical group of prospective elementary teachers. This fact not only supports the above assertions that the students increased their use of science learning skills, but it deserves some attention from professional educators who have voiced the above concerns over deficient science knowledge skills and lack of proper science teacher training exhibited by many prospective and practicing elementary teachers.

SKILLS ASSERTION #2: Many students increased their appreciation of various science learning skills during the course.

SUPPORT: Support for this assertion is provided by both the statistical surveys and the ethnographic methods.

1. SCIENCE LEARNING & TEACHING SKILLS (TABLE 9)

Each scale below is a 5-point Likert-type scale ranging from the most negative response on the left, through intermediate values to the most positive response on the right. The following coding was given for the numbered columns: 1 = not helpful; 2 = slightly helpful; 3 = somewhat helpful; 4 = very helpful; 5 = extremely helpful. All three of the following questions show that a higher percentage of the students' responses are showing a greater appreciation in developing different science learning skills.

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	not helpful 1	2	3	4	extremely helpful 5
Q-19: LABORATORY WORK					
pretest	3.7	11.1	33.3	33.3	18.5
posttest	0.0	5.6	7.4	42.6	44.4

Combining the two highest levels of perceived helpfulness on the pretest in Q-19 accounts for 51.8% of the students. On the posttest, the two highest levels have increased to 87% with a gain of greater than 25% in the highest level. A similar change occurs in Q-20 when 64.8% of the students recorded their pretest responses on the two highest levels and then increased to 85.1% of the students responses on the posttest.

Q-20: DEMONSTRATIONS: LECTURE & LABORATORY					
pretest	1.9	13.0	20.4	44.4	20.4
posttest	0.0	0.0	14.8	44.4	40.7

Further support for this assertion is given by a corresponding increase in the usefulness of Structured Reviews in Q-26. On the pretest, 57.4% of the students recorded the two highest levels of helpfulness. On the posttest, 92.5% of the students were in the two highest levels of appreciation.

Q-26: STRUCTURED REVIEWS PRIOR TO EXAMS					
pretest	0.0	7.4	35.2	27.8	29.6
posttest	1.9	1.9	3.8	28.3	64.2

2. Ethnographic Data

The following student quotations from the four Ethnographic Methods employed in this research compare well with the above survey questions by exhibiting a greater appreciation of various science learning skills, particularly those acquired in the laboratory experience. This shift gives support to the above assertion. Only a few examples from the Ethnographic Methods will be given here as evidence of this support. The reader is encouraged to read the numerous supportive responses in the appendicies.

A word of caution about the number of student responses is appropriate. As with the past assertions, the student responses are intertwined with Attitudes and Knowledge statements. However, in the case of appreciated science learning skills, the students' responses are also intertwined with their appreciation of science teaching skills. Therefore, the number of students out of 54 who are attributed as making statements about their increased appreciation of science learning skills should be treated as the minimum number of students who could have made such a statement. In other words, if 34 out of 54 students are attributed as making such a statement, the actual number of students could be higher but not lower than 34.

SPECIAL RESEARCH EXERCISE: (APPENDIX A) Although student quotations related to the greater development of science learning skills are found throughout Appendix A, 34 out of a possible 54 students volunteered clear statements about their greater appreciation of science learning skills. Although 34 students may not seem like a profound number, the reader should recall that the volunteered responses are listed in the Skills category only if they clearly emphasized a greater change in Skills than in Attitudes or

Knowledge. This listing also requires a large degree of artificial extraction of that quotation from an intertwined Attitudes-Knowledge-Skills statement. A representative example is given here:

M.L.: "LAB not only showed me the basic concept of longitudinal and transverse waves, but it also showed my many important characteristics of waves that I'm sure will help me explain alot more things in everyday situations and class!"

INTERVIEWS: (APPENDIX B) Many positive references related to the students' greater appreciation of science learning skills are found in the interviews. All 22 of the students interviewed have quotations showing a greater appreciation of these skills. An example follows:

P.H.: "Since this class, my confidence in learning science has gone up. I now feel capable of doing it. I felt stupid before that (this class) I didn't have it in me to learn science. Also, I am definitely more confident in teaching science."

TRANSFER OF LEARNING/TEACHING SKILLS: (APPENDIX C) Many quotations exhibiting greater student appreciation of science learning skills occur throughout this open-ended exercise. Due to the nature of this exercise almost all of the 54 students have made some comment about a greater appreciation of science learning skills. Here are several examples:

S.G.: "I'm sold on the hands-on laboratory experiences. I don't see how a lab could be any other way. I need to observe and manipulate materials. I need to cause interaction between things and observe the outcome."

S.B.: "The lab experience also pushes for hypothesizing, thinking things through and stretching my mind to figure things out. It makes science fun and clears up alot of questions that otherwise I would not have beeen able to see."

ANONYMOUS STUDENT EVALUATIONS: (Numbers on quotes refer to their order in APPENDIX D) Comments related to the greater appreciation of science learning skills are found throughout the anonymous student evaluations. About 38 statements out of 41 returned forms can be classified as such. Here is one example of such an anonymous response:

3) "This is one of the (few) classes I have taken at M.S.U. where I feel I have learned a great deal. I believe alot of it had to do with the lab. I was able to have a hands-on experience with what I was reading and learning in lecture."

SKILLS ASSERTION # 3: Many students increased their appreciation of various science teaching skills during the course.

SUPPORT: Support for this assertion is provided by both the statistical surveys and the ethnographic methods.

1. SCIENCE LEARNING & TEACHING SKILLS (TABLE 9)

Each scale below is a 5-point Likert-type scale ranging from the most negative response on the left, through intermediate values to the most positive response on the right. The following coding was given for the numbered columns: 1 = not helpful; 2 = slightly helpful; 3 = somewhat helpful; 4 = very helpful; 5 = extremely helpful. All three of the following questions show that a higher percentage of the students' responses are showing a greater appreciation in developing different science teaching skills.

	not helpful 1	2	3	4	extremely helpful 5
Q-42: LABORATORY APPROACH					
pretest	0.0	12.2	28.6	38.8	20.4
posttest	0.0	3.8	5.8	42.3	48.1

On the pretest, combining the two highest levels of perceived teaching-skill usefulness in Q-42 accounts for 59.2% of the students. On the posttest, the two highest levels have increased to 87% with a gain of greater than 27% in the highest level. A similar change occurs in Q-43 when 72% of the students recorded their pretest responses on the two highest levels and then increased to 86.5% of the student responses on the posttest. The highest level increased 24.3% from the pretest to the posttest.

Q-43: DEMONSTRATIONS & FILMS					
pretest	0.0	2.0	26.0	54.0	18.0
posttest	0.0	5.8	7.7	44.2	42.3

Further support for this assertion is given by a corresponding increase in the perceived teaching-skill usefulness of Structured Reviews in Q-48. On the pretest, 60% of the students recorded the two highest levels of usefulness. On the posttest, 78.8% of the students were in the two highest levels with a 30% increase in the highest level.

Q-48: STRUCTURED REVIEWS PRIOR TO EXAMS					
pretest	2.0	10.0	28.0	40.0	20.0
posttest	0.0	1.9	19.2	28.8	50.0

2. ATTITUDES TOWARD LEARNING & TEACHING SCIENCE (TABLE 2)

The scales below in Q-49 and Q-41 are 5-point Likert-type scales ranging from the most negative response on the left, through the intermediate values to the most positive response on the right. Q-50's scale is described within the question. Support of this assertion that students increased their appreciation of various science teaching skills could be inferred from the following questions. For example, in Q-49 and Q-50, making an inference between increased science teaching enjoyment and amount of time devoted to teaching science with greater appreciation of science teaching skills does not seem too difficult. However, other factors could influence the students' responses In Q-50, for example, the students experience in elementary schools may dampen their desire to devote 15% or more of their class time to science when they have seen few practicing teachers doing this. Let's look at Q-49 first.

Q-49: ANTICIPATED ENJOYMENT OF TEACHING SCIENCE TO CHILDREN

	VERY LITTLE				VERY MUCH
pretest	0.0	5.9	21.6	51.0	21.6
posttest	0.0	5.9	11.2	45.1	37.8

Combining the two highest levels of enjoyment in the pretest accounts for 72.6% of the student responses. On the posttest, the two highest levels have increased to 82.9% with a 16.2% increase in the highest level. A similar change occurs in Q-50 where 47.1% of the students reported their pretest responses on the two highest levels and then increased to 66% of the student responses on the posttest, in spite of the possible dampening effect mentioned in the previous paragraph.

Q-50: ANTICIPATED % OF TIME DEVOTED TO TEACHING SCIENCE

	<5%	5-10%	10-15%	15-20%	>20%
pretest	0.0	17.6	35.3	27.5	19.6
posttest	0.0	6.0	28.0	44.0	22.0

Q-41 was asked because it was discovered in previous courses and the pilot study that students science anxieties were high. This meant that some students deferred taking this course after their student teaching even though the course was intended to be taken during their sophomore year before their science methods course. In this research 20% of the students had done their STUDENT TEACHING. 76.9% of these students had taught in the upper elementary where they are traditionally expected to teach some science.

Q-41: DEGREE OF COMPETENCE FELT AFTER TEACHING SCIENCE.

	LOW	2	3	4	HIGH
pretest	7.7	0.0	15.4	46.2	30.8
posttest	14.3	14.3	7.1	57.1	7.1

On the pretest, 30.8% of the students rated their science teaching competence during STUDENT TEACHING at the highest level. After having completed this course and reflected on their student teaching in science, the students who had rated themselves at the highest level of competence had dropped from 30.8% to 7.1%. Also, note that the two lowest levels of competence rose from 7.7% to 28.6%. One reason given by a student for this rating drop was that now she had a much better idea of what competence can be. Another student said that after this course she could compare what she had done in relation to what she perceived she could have done in her student teaching. A third student interviewed during the Summer term made this remark:

S.B.: "Yes, it's alot of work, but it's a good way to decrease your anxiety about science. It's things you need to know to teach. I realized now how little I knew before this class and it makes you want to learn more."

These individuals lend support to the idea that a false sense of high competence may have existed before this course. After the course, the students may have perceived how much more competent they could have been and more importantly how much more they can become. This survey with the students' remarks support the assertion by showing a greater appreciation in science teaching skills by the students. A later literature reference will be made on how the importance of perceived teaching competence relates to teacher and student expectations.

3. <u>Ethnographic Data</u>

The following student quotations from the four Ethnographic Methods employed in this research compare well with the above survey questions by exhibiting a greater appreciation of various science teaching skills, particularly those acquired in the laboratory experience. This shift gives support to the above assertion. Only a few examples from the Ethnographic Methods will be given here as evidence of this support. The reader is encouraged to read the numerous supportive responses in the appendicies.

Again, a word of caution about the number of student responses is appropriate. As with the past assertions, the student responses are intertwined with Attitudes and Knowledge statements. However, in the case of appreciated science teaching skills, the students' responses are also intertwined with their appreciation of science learning skills. Therefore, the number of students out of 54 who are attributed as making statements about their increased appreciation of science teaching skills should be treated as the minimum number of students who could have made such a statement. In other words, if 34 out of 54 students are attributed as making such a statement, the actual number of students could be higher but not lower than 34.

SPECIAL RESEARCH EXERCISE: (APPENDIX A) Student references to the greater appreciation of science teaching skills are found throughout Appendix A. About 35 out of a possible students clearly stated this appreciation. Perhaps not a profound number, but recall that these are volunteered responses and recall also the artificiality of extracting these quotes from the students intertwined Attitude-Knowledge-Skills statements. An example follows:

M.L.: You allow us to work on our own, but you guide us through and never leave us feeling stupid, frustrated, or lost. That's what education is about. I do enjoy the things we learn and I will have this attitude with my children so 'they don't cringe when science is mentioned' like I used to."

INTERVIEWS: (APPENDIX B) Many positive references to the students' greater appreciation of science teaching skills are found in the Interviews. All 22 of the students interviewed show some greater appreciation of these skills. Two examples are given here:

P.C.: "Unfortunately I had the idea of having a classroom where I'd be doing the lecture, very structured, very didactic. I'd be lecturing and my students would be listening. I've got to change my mind about this and this course has helped because I've understood through my own lab experience--by working with other students and hearing my own peers speaking about it. In my own class, I'll encourage my students to talk among themselves. So it was a good experience with this approach. It has changed my mind about how to teach."

I.B.: "I will teach by showing a child rather than telling him because of my experience of this helping me."

TRANSFER OF LEARNING/TEACHING SKILLS: (APPENDIX C) Many quotations exhibiting greater student appreciation of science teaching skills occur throughout this open-ended exercise. Due to the nature of this exercise almost all of the 54 students have made some comment about a greater appreciation of science teaching skills. Here are several examples:

L.C.: "The hands-on, small group lab experiences have completely changed my attitude about how I can teach physical scieance and science in general. Prior to the class I wasn't exactly confident in my own ability to teach science. . . . This is really the first class that taught me how to apply what I learned in a classroom. I'm looking forward to using many of the activities/hands-on projects in my classroom next year. Good work Guys!!"

B.DEL.: "Beyond the concepts which I have learned, I value the teaching techniques employed--especially in lab. I hope I can make the learning of other subjects as enjoyable to my students as PHS 203 has been for me."

ANONYMOUS STUDENT EVALUATIONS: (Numbers on quotes refer to their order in APPENDIX D) Comments related to the greater appreciation of science teaching skills are found throughout the anonymous student evaluations. About 38 statements out of 41 returned forms can be classified as such. Here is one example of such an anonymous response:

1) "I think they did a super job! They are fine examples of teachers themselves. They make it interesting and you can tell they really care. I hope I can do as good a job as they! . . . I gained alot of good ideas for my elementary classroom."

*5) " This the best science class that I have had in terms of classroom application. My methods science was a waste of time. Thanks."

8) "This is one of the (few) classes I have taken at M.S.U. where I feel I have learned a great deal. I feel this is one course which will benefit me in my student teaching ... and in my future teaching."

COUNTER-EVIDENCE FOR SKILLS ASSERTIONS # 2 AND # 3: Some possible disconfirming evidence might be provided by the following anonymous student comments which occur in Appendix D.

2) "I feel you should try to circulate around the room more during lab. You seemed to stick mostly to one group in helping them and in asking them questions. This bothered me a bit. Otherwise, everything else was okay."

3) "A film during lecture would be a welcome change to lectures."

*4) "At times, I feel that we were rushed -- very rushed .... Consequently , I don't think lab was as valuable as it could have been ...."

The above student comments do not directly criticize specific learning and teaching skills, but they exhibit some displeasure towards several teaching behaviors. Let's assume that they indicate a total lack of appreciation for science learning and teaching skills. If true, these 3 cases would not be enough to refute the stated assertions when compared to the impressive statistical and ethnographic evidence that supports the assertions.

RELATING SKILLS ASSERTIONS # 2 AND # 3 WITH LITERATURE: Both assertions have strong supporting data. In summary, the supporting data shows that:

1) A large majority of the students had a low appreciation of various science learning and teaching skills.

2) A majority of students increased their appreciation of various science learning and teaching skills during this course.

3) Students attributed this increase to:

a) The hands-on, small-group laboratory for providing them with the opportunity to develop and use their science learning skills.

b) The role model demonstrated by the laboratory instructors in providing a positive learning environment that they could appreciate as important for their own teaching.

c) The lab instructors' attitude, knowledge and science teaching skills in providing the students to practice their own science learning skills and to appreciate various science teaching skills.

The following discussion of these findings draws on pertinent literature which emphasizes the important role of developing science learning and teaching skills. The following literature is consistent with the notion that prospective and practicing elementary teachers need to increase their appreciation of various science learning and teaching skills. This literature will be presented in the following sequence: 1) description of poor science teaching methods, 2) a description of what good methods should include, 3) the importance of elementary teachers possessing good science teaching methods, 4) the need to revise elementary teacher programs for the acquisition of these skills, and 5) description of several instructional considerations for maximizing the acquisition of these skills. This section will conclude with how the research indicates that this specially designed content course appears to achieve a considerable part of the above point # 5. The numbers listed at the beginning of the following paragraphs correspond to the above numbered sequence.

1) The first two excerpts describe the existence of poor science teaching methods, while the following quote indicates what a superior elementary science class should include in its methods and environment. From Daedulus: (Spring 1983), the Atkin article gives the following description:

> The most common form of teaching in American schools is still the recitation: the teacher asks a question; the child answers it, preferably in the words of the textbook. Typically, the teacher assigns, the children recite, the teacher tests, and then--sometimes--the class participates in discussion. Further more the questions teachers ask in science frequently focus on definitions and terminology. The essence of the children's task is to search the text for a sentence that contains the correct answer (Aktin, p.183).

From Project Synthesis, Volume 3 (1981), Harms & Yager describe a typically poor elementary science class:

> The typical elementary science experience of most students is at best very limited. Most often science is taught at the end of the day, if there is time, by a teacher who has little interest, experience or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will probably come from a textbook selected by a committee of teachers at the school or from teacher-prepared worksheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the student but selected because it is 'in the book' (Harms & Yager, p. 73).

2) Harms & Yager later describe in the this excerpt what they believe would be a superior elementary science experience:

> Instead the classroom should be the place to excite students' curiosity, build their interest in their world and themselves and provide them with opportunities to practice the methods of science. Such a program can be made conceptually rich by introducing exciting and important phenomena to be observed and analyzed, but

> it should not reflect a need to cover a syllabus of content in all science disciplines (Harms & Yager, p. 75).

3) The following 2 excerpts state the importance of providing the proper science learning experience early in a child's educational experience by elementary teachers. In Project Synthesis, Volume 3 (1981), the importance of providing positive science experiences for young children is emphasized:

> During these early years, they form their basic attitudes, patterns of thought, and modes of behavior. It is, therefore, during these years that particular attention must be given to establishing the attitudes and modes of inquiry that are associated with scientific enterprise--- its processes and content. (Harms & Yager, p. 73).

A similar line of argument based on learning theory is proposed by Bloom in his Stability and Change in Human Characteristics (1964). He emphasized that acquisition of the proper science experiences and behaviors early in one's life is significant, if not crucial, because of the sequential nature of human development. Bloom states:

> It is much easier to learn something new than it is to stamp out one set of learned (negative) behaviors and replace them by a new (positive) set (Bloom, p. 215).

In addition, Bloom emphasizes the crucial importance of the early learning environment because it shapes certain human patterns during "their most rapid periods of formations." Since the potential for harm appears to be greater with young children, the need to revise elementary teacher programs so that the proper skills are developed in elementary teachers for providing young children with early science experiences that are both and effective.

4) The need for revision in professional programs was recognized in the Holmes Group Report On Tomorrow's Teachers (1986) when they advocated a greater coordination between methods and content experiences in university teacher training programs. One recommendation is:

> Professional programs need to revised .... Methods and content courses need to be complementary and compatible with one another and develop an ethic of inquiry and professional judgment (Holmes Group ..., p. 55).

5) The incorporation of Role-modeling into some of the revised professional programs is one instructional strategy that could maximize the aquisition of new science teaching skills for prospective elementary teachers. One aspect of role-modeling is what Bandura in Psychological Modeling (1971) calls "observational learning". This invlolves the idea of acquiring new patterns of behavior (skills) by observing the performance of others. Although observing by itself is too passive, the type of modeling in science teaching requires a very active role on the part of both teachers and students. The lack of this highly-concerned, active-teaching model could result in the negative role models described by Gallagher (1986) about secondary science teaching. He said:

> Secondary science teachers' role models were university professors who tend to be presenters of information, but who rarely are concerned with students' learning. Typically, the university professors' model of instruction is similar to that observed in secondary schools: present information, give assignments, evaluate performances---good students will learn and

> the rest will not. When students do not learn or lack motivation, it is perceived as the fault of the students and not the fault of the teachers (Gallagher,p.9).

Several aspects of positive role models are the attitudes, knowledge and skills of the university science educator. As with any level of education, the instructor is the key. Educating Americans for the 21st Century(1983) states:

> The teacher is the key to education--the vital factor in motivating and maintaining student interest in mathematics, science, and technology (NSB Report, p.27)

University staff must be aware of the influence of their expectations on the prospective elementary teachers'achievement. Lezotte, et al, in School Learning Climate & Student Achievement address the importance of expectation in the following 2 quotes:

> This involves the self-fulfilling prophecy in which expectations of achievement are communicated by the teacher through both overt and subtle means. The student then conforms to the level of expectation rather than to his or her actual level of ability. The teacher, in turn, perceives this performance level as the actual ability level, which confirms the original judgment (Lezotte, p. 52).

> ...the fact that the messages teachers intend to communicate and the messages the students actually perceive may be quite different. No matter how well-intended the message, its real effect is grounded in the student's perception of the message (Lezotte,p.103).

University staff must also be aware of certain factors that should be included in their course designs that will increase the probability of producing "lasting" positive change in prospective teachers' behavior. Ball-Rokeach, Rokeach, and Grube (1984) give some ideas for producing stabilized change in individuals with this quote:

> Processes of both stability and change may be initiated in persons if information contains the following characteristics: 1) appeals to the curiosity. 2) is potentially useful. 3) does not require too much specialized training or effort to understand. 4) appears credible and intuitively correct. 5) within the repertoire of the person to act upon the information, either to alleviate dissatisfaction or enhance satisfaction. Satisfaction reinforces competence and dissatisfaction becomes an impetus for change. 6) The information is presented under conditions that minimize ego defense (Ball-Rokeach, p. 36).

The staff's emphasis on concrete, first-hand, small-group lab experiences contributed to the positive development and appreciation toward science learning and teaching skills. Prospective teachers attributed the laboratory experience as being extremely important in providing them with a greater appreciation of science learning and teaching skills. This can only result in better elementary science teaching for our nations' children. The related literature demonstrated the importance of the laboratory experience.

The above descriptions and concerns from the professional education literature are consistent with the needs and benefits described the students who experienced this specially designed course. They are also consistent with the concerns and instructional considerations of the staff who designed this special course. It has previously been estab lished that the researched student population could be identified as typical for prospective elementary teachers. Therefore, the dramatic in-depth PROFESSIONAL benefits expressed by the students as improving their ability to aquire and appreciate various science learning and teaching skills was accomplished by a group of typical elementary education majors. This fact not only supports the above assertions that the many students increased their use and appreciation of various science learning and teaching skills, but it demands some attention from professionals who have voiced concern over deficient science teaching skill and the need to revise existing professional programs for prospective and practicing elementary teachers.

CHAPTER FIVE

CONCLUSIONS & IMPLICATIONS

This chapter first will summarize the purpose of the study and the data interpretations. Then it will review the study's assertions and conclusions. Finally, it will state some implications of the study for educational practice and further research.

Description of Study

A physical science content course was designed to provide prospective elementary teachers with an integrated learning experience that would: 1) improve their attitude toward science and their ability to learn and teach science 2) increase their knowledge of certain scientific concepts, and 3) develop and/or improve their skills for learning and teaching science. The above 3 goals were treated as being equally important by the course instructors in this model. The course extended for 10 weeks with 3 hours of lecture and 3 hours of laboratory each week.

A major strategy for achieving these goals was the hands-on laboratory experience where the staff acted as role models for the type of science teaching that they hoped the prospective elementary teachers would grow to appreciate as being a model for their own science teaching. Qualities of good science teaching that the staff tried to project involved the aspects of attitudes, knowledge and skills. The attitude aspects included enthusiasm, high expectations, constant concern for the students progress, and the production of a non-threatening environment in which the student could ask questions without fear of ridicule or punishment. The knowledge aspects included the understanding of science concepts that were basic to comprehending certain expressions of nature and could be related to the student's daily life. The skills aspects included hands-on, concrete learning experiences where the students used science learning skills in acquiring a working knowledge of science concepts. These skills included observation, manipulation, experimentation, testing hypotheses, making conclusions, and understanding sources of error.

The laboratory instructors in this model made frequent references to how the knowledge and skills related to the students' daily lives and to their future teaching experiences. They also required that these relationships be demonstrated in the students' laboratory reports. The students worked usually in small laboratory groups ranging from 2 to 4 partners. The laboratory instructor would teach the whole class and also individual groups. The instructor would use a guided-discovery approach which often involved the instructor asking a question in response to a student's question and allowing the lab group to discuss it and act on it at their own pace.

In addition, the lectures were demonstration-oriented with a strong coordination of concepts with the textbook and laboratory experiences. The professed student benefits from this special course led to a formal research study with the following Problem Statement:

> What effect does this specially designed physical science class with an emphasis on laboratory activities have on the attitudes, knowledge and skills of prospective elementary teachers regarding the learning and teaching of science?

Research Design and Data Interpretation

The research method for the above problem involved a blend of experimental and ethnographic approaches. This blend was believed necessary for investigating the complex relationships existing in this study. The experimental approaches used a pretest-posttest design. These approaches included background, attitude, and skills surveys along with knowledge questionnaires. The ethnographic approaches included two different open-ended exercises, interviews, and anonymous student written evaluations.

Paired-t tests were used for statistical analysis on the experimental instruments. Student responses on pretests and posttests were compared for a statistical significance at the 0.05 level on the attitude and skills surveys. Triangulation was used on the ethnographic methods. All 4 ethnographic data sources were compared for consistent results. Experimental and ethnographic data were used to generate assertions and specific examples from the Datus Corpus were used to evaluate them. Conclusions were then drawn and compared with relevant literature.

Assertions and Conclusions

The students entering this course as described by the background survey easily fall within the description of the national norm of prospective elementary teachers. Therefore, any student accomplishments indicated by this research should not be construed as being achieved by an exceptional group of students.

The following assertions and conclusions are organized under the 3 primary research themes: Attitudes, Knowledge and Skills which are named in the problem statement. Detailed discussion has occurred in Chapter 4.

ATTITUDE ASSERTIONS & CONCLUSIONS

Assertion # 1: Most students' anxiety about the learning and teaching of science decreased during this course.

Very strong support for this assertion is provided by both statistical and ethnographic data. The background survey indicates that about 3/4 of the students would never have taken this course if it had not been required. The attitude surveys exhibit a dramatic shift from high anxiety toward science and physics at the beginning of the course to a much lower anxiety at the end of the course. All four sources of ethnographic data contain numerous student statements about their lower anxiety towards the learning and teaching of science and their increased enjoyment of science. Several possible examples of little or perhaps no decrease anxiety did not weaken this assertion.

Assertion # 2: The laboratory experience provided during this course was an extremely important contributor in decreasing most students' anxiety about the learning and teaching of science.

Dramatic support for this assertion is provided by the ethnographic data. The statistical surveys did not try to measure a relationship between student anxiety and the laboratory experience. All four sources of ethnographic data contain extensive evidence emphasizing the benefits of the laboratory experience in decreasing student anxiety toward science and science teaching while increasing their enjoyment of science. Only 2 examples of student comments indicating some possible lack in the laboratory experience for decreasing anxiety could be found.

In conclusion, there appears to be three prominent factors that the students most often attribute to the benefits expressed in Attitude Assertions # 1 and # 2. The following factors with key words emphasized appear to be relatively equal in importance:

1) The EXCITEMENT of observing and manipulating the phenomena first-hand, along with predicting and testing results.

2) The SECURITY of being able to ask naive questions about science content and skills without the fear of ridicule or punishment.

3) The FRIENDSHIPS and TRUST they developed with members of their small laboratory group and their laboratory instructor.

KNOWLEDGE ASSERTIONS AND CONCLUSIONS

Assertion # 1: Many students increased their ability to express their understanding of wave phenomena using scientific terms during this course.

Assertion # 2: Many students gained an understanding of wave phenomena that was beyond the memorization level of learning complexity and achieved a knowledge retention period that was greater than short-term recall.

Dramatic support for these two assertions is provided by statistical and ethnographic data. In support of Assertion # 1, the "open-ended" wave questionnaire and the "wave-definitions" questionnaire show an large increase in the students' ability to understand and apply scientific terms in the explanation of wave phenomena. All four sources of ethnographic data indicate a consistent shift toward a greater student understanding of wave phenomena during this course. In support of Assertion # 2, the "Sketch, Label, & Explain Wave-Patterns" questionnaire and the "Wave Knowledge-Transfer" questionnaire provide strong evidence that the students can apply their understanding of wave phenomena to complex and novel situations that cannot be memorized. In addition to the "Wave Knowledge-Transfer" questionnaire, the "Eight-Week Follow-up" questionnaire shows a high rate of retention of the students' knowledge for a period up to 8 weeks after having been tested on that knowledge for a grade. All four sources of ethnographic data contain numerous student comments exhibiting a level of understanding beyond memorization and a retention of knowledge beyond short-term recall. A few examples of possible counter evidence did not weaken either Assertion # 1 or Assertion # 2.

In conclusion, there appears to be 4 prominent factors that the students most often attributed to the benefits expressed in Knowledge Assertions # 1 and # 2. The following factors with key words emphasized appear to be relatively equal in importance:

1) The laboratory instructors' HIGH CONCERN for their UNDERSTANDING of the concepts, not memorizing them.

2) The HANDS-ON laboratory experience that emphasized science learning SKILLS.

3) The DYNAMIC teaching techniques of the laboratory instructors which used ANALOGIES and GUIDED-DISCOVERY approaches.

4) The instructors' common REFERENCES of how the laboratory activities can relate to the students' DAILY LIFE and potential TEACHING experiences.

SKILLS ASSERTIONS AND CONCLUSIONS

Assertion # 1: Many students increased their use of science learning skills during this course.

Very strong support for this assertion is supplied by the four sources of ethnographic data. Although the Skills survey measures indirectly the use of science learning skills, no statistical survey directly measured the use of these skills. The ethnographic data provides extensive student description of the development and/or improvement of their science learning skills based on their first-hand laboratory experiences. The type of skills described by the students include observing, predicting, manipulating, testing hypotheses, and discussing results.

Assertion # 2: Many students increased their appreciation of various science learning skills during this course.

Assertion # 3: Many students increased their appreciation of various science teaching skills during this course.

Abundant support for both assertions is provided by statistical and ethnographic data. The Skills survey supports both assertions when it shows an impressive shift toward greater student appreciation of various science learning and science teaching skills. The greatest increases in appreciation occur in the areas of laboratory activities, demonstrations and structured reviews as benefiting both science learning and science teaching skills. It should be emphasized that both assertions changed in consort. Some additional impressive evidence for Assertion # 3 comes from the attitudes survey regarding those students who had already done their student teaching before this course. After completing this course, many of these individuals perceived how much more competent they could have been during their student teaching and more importantly how much more competent they can become in their future teaching. All four sources of ethnographic data contain numerous student accounts of greater in-depth professional benefits regarding their improved ability to acquire and appreciate various science learning and teaching skills.

In conclusion, there appears to be several prominent factors that the students most often attributed to the benefits expressed in Skills Assertions # 1, # 2 and # 3. The following factors with key words emphasized appear to be relatively equal in importance:

1) The superiority of HANDS-ON laboratory experiences over other types of learning experiences for providing the students with the opportunity to DEVELOP and USE their science learning SKILLS.

2) The ROLE MODEL provided by the laboratory instructors for the type of teaching they hoped their students would grow to appreciate as important for their own teaching skills.

3) The ATTITUDES, KNOWLEDGE and science teaching SKILLS of the laboratory instructors in providing the students with the opportunity to develop and appreciate various science learning and teaching skills.

Examining closely the above key features, it should become apparent that this model is describing the students as actually developing and using their skills as opposed to being passive recipients of knowledge or participates in "cook-book" labs where they know the answers before doing the "experiments". In the first feature, the students are describing the development of their skills. The second feature describes the students being able to see an appropriate role model demonstrate the desired skills. The third feature describes the students being able to practice these skills.

The above procedure of the students developing, seeing and practicing the desired skills becomes an important feature in this course. What often happens in other courses is: 1) the students only hear about the desired skills, 2) they do not get to see a role model using the skills and/or 3) they do not get an opportunity to use or practice the skills. As indicated in step # 3 of the above prominent features, this specially designed course model in its best form emphasizes the use of the lab instructor as a coach in which he is using guided-discovery techniques on the students.

Conclusions in Reference to the Problem Statement

The following conclusions as were the previous detailed conclusions are supported by both statistical and ethnographic methods used in this research. A brief summary in reference to this study's problem statement follows.

This specially designed physical science with an emphasis on laboratory activities had a dramatic effect on improving the attitudes, knowledge and skills of prospective elementary teachers regarding science and science teaching. The benefits included a large decrease in science anxiety, a large increase in their ability to understand and apply their new knowledge about wave phenomena, and a dramatic improvement in their ability to use and appreciate various science learning and teaching skills.

A summary of the course model used in this research occurs under the "Description of the Study" section at the beginning of this chapter. In addition, the conclusions in the Attitude, Knowledge and Skills sections in this chapter contain key elements of this model. These sections if reviewed by the readers should provide sufficient insight into the model referred to in the following Implications section.

In reading these sections, it should be emphasized that it is not just the key elements in this model that are important but the integration of these elements that produce the model's effectiveness. Dealing with the elements separately, as done in other studies, has not been as successful. For example, educators have been concerned with changing attitudes, but typically they have not considered doing it in a content course. Often, they have not considered a model in which the development of attitudes, knowledge and skills are treated and coordinated as equal course objectives.

Implications For Practice

Implications for practice and future research are numerous. Several major implications for educational practice will be given first followed by several implications for future educational research.

A major purpose of this study was to investigate a science content course that was designed to increase the scientific knowledge of prospective elementary teachers, to address the problem of high science anxiety and to improve the poor science learning and teaching skills that this student population has typically possessed. The positive results from this model indicate that a typical group of prospective elementary teacher can benefit from this type of specially designed course. This model appears to address the concerns of many science educators and therefore, has several major implications for practice. The first implication addresses Elementary Teacher Educators, the second addresses other university educators and the third addresses the need to do more of this type of teaching on the elementary and secondary levels as well. The fourth implication is for educational researchers.

IMPLICATION # 1:

The data from this study strongly suggest that Elementary Teacher Training Programs should incorporate this model for improving the SCIENCE attitude, knowledge and teaching skills of their prospective elementary teachers. This model has provided an effective and efficient means for addressing successfully three important areas of deficiency in prospective elementary teachers. This model has provided substantial improvements in the areas of attitudes, knowledge and skills of prospective elementary teachers regarding science and science teaching. This model has provided an effective means for decreasing science anxiety and other negative attitudes toward science while increasing the acquisition of positive attitudes towards science through supplying a non-threatening learning environment. This model has provided the means for increasing the students' working knowledge of science beyond memorizing and short-term recall by supplying a hands-on laboratory experience. This model has provided a means for developing and/or improving the students' science learning and teaching skills which can be transferred to novel situations by supplying the laboratory instructor as a role model for these skills.

IMPLICATION # 2:

Data also implly that the role modeling of teaching skills by the university instructors could be used for improving the teaching skills of prospective elementary teachers in OTHER subject content areas. There is little reason to believe that this model can only be applied to a science content area. Deficiencies in the areas of social studies, liberal arts, mathematics, etc. should decrease using the same model.

IMPLICATION # 3:

Data also suggest that public education should incorporate this teaching model for improving the science LEARNING skills of all its students. Traditionally, the majority of students who become elementary teachers have been poor in the sciences. A model which is effective in improving the attitudes, knowledge and skills of these students regarding science should also be effective in improving these areas in the general student population at both precollege and college levels. Therefore, this model may provide an effective means for improving the scientific literacy of this nation.

IMPLICATION # 4:

The research design which involves a blend of experimental and ethnographic approaches offers an effective and efficient means for approaching a complete understanding of complex learning situations. Most educational research involves complex learning siutations. The tentativeness of many research studies could be related to the research methodoloy of using either statistics or ethnographic approaches. A blend of approaches offers the possible of maxmizing the strengths of each approach while minimizing their weaknesses.

Implications for Future Research

Further research should be conducted to verify the above implications. The specific benefits of role modeling and hands-on laboratory experiences should be studied in the context of this course model. The ethnographic data in this research indicate that the students believed that the role modeling by the instructors and the hands-on laboratory experience were among the most effective strategies in improving their attitudes, knowledge and skills regarding the learning and teaching of science. Therefore, a more intense investigation into these two features should be conducted for a more profound understanding of their roles in this model.

Comparative studies in Student Teaching should be conducted comparing the effectiveness of the students who have experienced this model with the effectiveness of the students who have not experienced this model in their training programs. This research studied these students over a ten-week period. Although informal follow-up was done, there is a need for extensive follow-up for investigating this model's carry-over benefits into practice.

Comparative studies should include the use of this model in in-service teaching programs. As with the pre-service studies, the effectiveness of groups using this model could be compared to effectiveness of groups not using this model.

Further research could be conducted in comparing this model where attitudes, knowledge and skills are treated as equally important with models which vary the importance of each in different combinations. Most studies have tried to influence the above areas separately, but with little success. An important feature of this model is the integrated treatment of attitudes, knowledge and skills as equally important. Greater insight into this integration process might be achieved by varying the emphasis of each area and then comparing the results with the model in which they are equally emphasized.

APPENDICES

APPENDIX A: ETHNOGRAPHIC DATA

The following collection of student quotes in Appendicies A, B, C and D are referred to in this research as "Ethnographic Data". Included in the "EthnographicData" are student quotes from "The Special Research Exercise", "Interviews", "Transfer of Learning/Teaching Skills", and "Anonymous Quotes". The "Special Research Exercise" instrument is on page 2. This instrument was given to each student as a take-home exercise in the middle to each term after the Sound and Light units.

CATEGORIES FOR THE "SPECIAL RESEARCH EXERCISE" QUOTES

UNDERSTANDING OF WAVES: SOUND AND LIGHT
Student quotes: Spring term, p.182; Summer term, p.192.

EFFECTS ON ATTITUDE
Good Role Model: High Teacher Concern
Student quotes: Spring term, p. 183; Summer term, p. 192.

Less Anxiety, More Enjoyment, Confidence in Teaching
Student quotes: Spring term, p. 184; Summer term, p. 193

EFFECTS ON LEARNING & TEACHING
Good Role Model: Teaching Techniques and Resources
Student quotes: Spring term, p.185; Summer term, p. 194

Scientific Processes: Activity Oriented Skills
Student quotes: Spring term, p. 185; Summer term, p. 196

Easier Learning: Concrete Lab Experiences
Student quotes: Spring term, p. 186; Summer term, p. 197

Small Group Environment: More Individual Involvement
Student quotes: Spring term, p. 187; Summer term, p. 197

Relevance to Daily Life
Student quotes: Spring term, p. 187; Summer term, p. 198

LAB COMPARED TO OTHER COURSE EXPERIENCES
Student quotes: Spring term, p. 188; Summer term, p. 199

COMPARISON WITH OTHER CLASSES: SCIENCE, METHODS, ETC.
Student quotes: Spring term, p. 190; Summer term, p. 201.

CLASS DESIGN: LABS, LECTURES, ETC., COMPLIMENTARY AND REINFORCING ASPECTS
Student quotes: Spring term, p. 191; Summer term, p. 202.

SUGGESTIONS FOR IMPROVEMENTS
Student quotes: Spring term, p. 191; Summer term, p. 202

SPECIAL RESEARCH EXERCISE

Special Research Exercise: You may refer to your comments on benefits, etc. in your laboratory write-ups: Metrics, Waves, Shadows, Pinhole Camera, Diffraction Grating, Color Shadows, Lenses.

Please put your name, date, section, on an 8 1/2 x 11 paper. Use as many sheets as you wish. We need your thoughtful, honest impressions. Thank you.

1. Reflect on how hands-on, visual, small-group laboratory have helped your understanding of waves & sound. Refer to specific activities such as slinkies, resonance tube, ripple tank, etc. and also to specific ideas like wave type, diffraction, interference, refraction, etc.

2. Reflect on how laboratory experiences have helped your understanding of waves and light. Refer to activities such as Shadows, Pinhole Camera, Colors, Lenses, etc. and also to ideas like how light travels, Reflection & Absorption, "Fuzzy" images, Color Pigments & Color Primaries, Eye Problems, etc.

3. Has the informal, small-group laboratory environment improved your enjoyment of science and helped you in learning the concepts? Please be specific in your comments, using examples if possible like individual help, teaching analogies, time for questions, etc.

4. In developing a "Scientific Attitude" and learning science, how do the benefits of the laboratory experience compare to other aspects of this course. Please be specific in your comments, if possible referring to textbook, problem sets, lecture, etc.

NOTE IT IS NOT NECESSARY TO USE THE SUGGESTED ACTIVITIES & IDEAS IN YOUR ANSWERS. YOU USE ANY ACTIVITIES OF IDEAS OF YOUR CHOOSING.

SPECIAL RESEARCH EXERCISE:
LABORATORY EXPERIENCES: SPRING 1985, SECTION 1

UNDERSTANDING WAVES: SOUND & LIGHT

J.C., 4-29-85: "Using a slinky helped me to remember the difference between longitudinal and transverse waves because a slinky is such a simple common thing, which is easy to remember. I bet I would have never understood sound theories without hands-on experiments and presentations."
J.C., 4-29-85: "The lab on eye problems was neat because I never knew why people were farsighted or nearsighted. I even explained it to my Mom last weekend after she had been to the eye doctor for new glasses! She was so impressed. (So was I that I could apply science to everyday life.)"
T.R., 4-29-85: "Slinkies helped me to understand transverse and longitudinal waves. I was able to see the different movement of the two waves. The ripple tank ... was an important visual aid. Wave properties in a ripple tank allowed you to see diffraction, interference, refraction, etc. I found the ripple tank to be enjoyable."
T.R., 4-29-85: "Before the laboratory dealing with light I never considered light as being a wave, but I found out some fascinating facts about light. . .why shadows form. During this lab your hands were actually doing the work to form shadows. The lab allowed me to answer questions related to everyday life."
T.R., 4-29-85: "Diffraction grating and color shadows allowed your visual senses to work. By actually seeing the different colors (combining, separating, etc.) on the screen allowed me to remember the different color combinations."
T.R., 4-29-85: "Taking pictures using a regular camera I always knew light played an important part. But by using the pinhole camera, I know why some pictures are over-exposed or under-exposed and I feel I have a better understanding on how to improve my pictures. The pinhole camera answered some of my questions concerning picture taking."
M.L., 4-29-85: "The most simple understanding of waves that I thought would help elementary children (and me too!) is the demonstration with the slinky. I saw clear as day what a transverse and longitudinal wave were."
M.L., 4-29-85: "The resonance tube proved that there are many frequencies that are different and that waves differ in many ways because of this--There are zillions upon zillions of frequencies!! And we can only hear a small fraction of them!"
M.L., 4-29-85: "Lab work gave me a visual image of how waves work--how they bend and what happens to them with interference both destructive and constructive and the effects it can have like hearing beats or pulses and "constructively" destroying a bridge."

P.H., 4-29-85: "The ripple tank especially gave me my visual images of what diffraction, interference and refraction looked like so that I had a picture or idea of these event and not just a definition; alot of words which have no meaning until applied to an actual event."
P.H., 4-29-85: "When I think of each of these types of waves, I can picture in my head the motion of the source (hand) and the direction the slinky was traveling. Now when I have to define either or use either one I can use my images to help me out."
M.C., 4-29-85: "The ripple tank was an excellent way to help me see wave movement. If I hadn't seen the waves in lab and how they move I couldn't have visualized sound waves and how they diffract, interfere and refract."
M.C., 4-29-85: "It (visual, hands-on experiences in lab with ripple tank, tuning fork, slinky, etc.) helped me understand something very abstract--by using concrete examples, it helped me see something I can't see and how it works such as sound and waves."
M.A., 4-29-85: "It's one thing when you hear definitions of terms, but when I saw diffraction, reflection, refraction, and interference (in the ripple tank), I really felt I knew what the terms meant."
C.S., 4-29-85: " The slinkies helped me understand how waves travel. The ripple tank helped me understand how waves act. The resonating tubes were especially good for helping me to understand that the natural frequency of the tube was being matched."
B.D., 4-29-85: "The ripple tanks were, I think, the most effective mainly because they showed exactly what waves look like when being diffracted, etc."

EFFECTS ON ATTITUDE
Good Role Model: High Teacher Concern for Students
J.C., 4-29-85: "There is always a chance for questions and I feel like a person not a number which is a rare thing in such a large university. The lab instructors really seem to care if we are undestanding and picking up the concepts. I have enjoyed science for the first time in a long time. I hope I can present science in the same way to kids in my classroom."
T.R., 4-29-85: "True . . . has an average of 15 students in his lab, but I feel during a lab if I have a question he is willing to answer it and help me to get an understanding. If he does not have enough time during lab , he is willing to help before and after lab."
M.L., 4-29-85: ". . . thank you for enjoying what you do, for going out of your way to help. Because you enjoy and understand what you do, you have set a fine example to me."
M.L., 4-29-85: "You guys go out of your way to make sure understanding occurs. You really care. It makes me care and I feel you are a prime example of what kind of teacher I want to be!"

<u>P.H., 4-29-85:</u> "The time for questions and individual help is wonderful. I don't feel uncomfortable about asking for help and it's nice to know that the door is open for that help. . . Excellent!"
<u>M.C., 4-29-85:</u> "They have a deep desire to <u>want</u> the student to understand and are <u>very</u> concerned if they don't. I must say again, it's not only the labs and lectures I so enjoy, it is the instructors themselves who have made science for me a most enjoyable and fun experience."
<u>M.A., 4-29-85:</u> "I really like all the attention he gives us. He doesn't just sit there while we do the lab. He actually 'does it' along with us."
<u>C.S., 4-29-85:</u> "Everyone is on a first name basis and I think this helps keep it informal and non-threating."

<u>Less Anxiety, More Enjoyment and Confidence in Teaching</u>
<u>J.C., 4-29-85:</u> "I also enjoyed learning about colors. This was something I had never had before. It was fun to see all the colors made on the screen. I felt like a little kid again--oohing and aahhing!"
<u>J.C., 4-29-85:</u> "I have enjoyed science for the first time in a long time. I hope I can present science in the same way to kids in my classroom."
<u>J.C., 4-29-85:</u> "Having an informal, friendly environment to work has really improved my enjoyment of science. I dreaded this course, because I thought it would be dull and boring. But it's turned out to be so interesting and even fun! I haven't had fun with science since about 6th grade. It started to be boring in about 7th grade and up."
<u>T.R., 4-29-85:</u> "Science has always been my worst subject. I might not leave the class with a 4.0, but I will leave the class full of knowledge and willing and anxious to learn more. Before this class I was turned off to science. Because I was afraid that I would not receive anything from it. But this class has showed and proved me wrong. Thanks . . .!"
<u>M.L., 4-29-85:</u> "I do enjoy the things we learn and I will have this attitude with my children so 'they don't cringe when science is mentioned', like I used to."
<u>P.H., 4-29-85:</u> "Small group lab has definitely improved my enjoyment of science. The atmosphere is relaxed, not tense, and informal--allowing for alot of open discussion and participation. I don't feel inhibited anymore to take guesses or make conclusions about what is happening in lab, because I know and feel it's okay to do so and I won't be penalized for my wrong guesses."
<u>M.C. 4-29-85:</u> "I cannot say enough about the friendly, informal, concerned lab environment. It has definitely improved my attitude about science. I look forward to lab because even though I'm discouraged at times because it's so hard for me to comprehend some concepts. But it is always comforting to know there is always someone, including the lab instructor, there to help me."

M.C., 4-29-85: "I must say again, it's not only the labs and lectures I so enjoy, it is the instructors themselves who have made science for me a most enjoyable and fun experience."
C.S., 4-29-85: "Everyone is on a first name basis and I think this helps keep it informal and non-threating."

EFFECTS ON LEARNING & TEACHING SKILLS

Good Role Model: Teaching Techniques and Resources
J.C., 4-29-85: "I hope I can present science in the same way to kids in my classroon."
M.L., 4-29-85: "The most simple understanding of waves that I thought would help elementary children (and me too!) is the demonstration with the slinky. I saw clear as day what a transverse and longitudinal wave were."
M.L., 4-29-85: "Seeing this (mixing colors) on the screen, it still baffled my mind. I had to see it to believe it. I think that it is extremely important for my class to experience and be able to explain it."
M.L. 4-29-85: "You allow us to work on our own, but you guide us through and never leave us feeling stupid, frustrated, or lost. That's what education is about. I do enjoy the things we learn and I will have this attitude with my children so 'they don't cringe when science is mentioned', like I used to."
M.C., 4-29-85: "I especially liked this (pinhole camera lab) because I will surely have my class make such a camera-it's something I will never forget."
M.A., 4-29-85: "I will definitely use this experiment (ripple tank) in my classroom."
B.D., 4-29-85: "The lab and recitation are helpful because it is a very friendly atmosphere. We can ask questions and not feel dumb by asking them. Also when we ask questions we don't just get the answer. We're asked to think for ourselves and guided to the correct answer."
S.D., 4-29-85: "The lab atmosphere has been very helpful. People don't mind helping each other. . . There is ample time for questions concerning lab material."

Scientific Processes: Activity-Oriented Skills
T.R., 4-29-85: "Diffraction grating and color shadows allowed your visual senses to work. By actually seeing the different colors (combining, separating, etc.) on the screen allowed me to remember the different color combinations."
M.L., 4-29-85: "Lab work gave me a visual image of how waves work--how they bend and what happens to them with interference both destructive and constructive and the effects it can have like hearing beats or pulses and "constructively" destroying a bridge."

M.L., 4-29-85: "Seeing this (mixing colors) on the screen, it still baffled my mind. I had to see it to believe it. I think that it is extremely important for my class to experience and be able to explain it."
P.H., 4-29-85: "Both (lenses & colors) help to give visual images of several concepts taught in lecture and it lets us apply and experiment with these concepts to see if they were correct."
P.H., 4-29-85: "The atmosphere is relaxed, not tense, and informal--allowing for alot of open discussion and participation. I don't feel inhibited anymore to take guesses or make conclusions about what is happening in lab, because I know and feel it's okay to do so and I won't be penalized for my wrong guesses."
M.C. 4-29-85: "I was fascinated to understand how glasses (lenses) work and how people are far and near-sighted. By having to actually measure--move back and forth the object and lense and screen, I could understand perfectly how people see. Without this demonstration, I couldn't have understood how when focus point comes behind the retina of a person he is farsighted. Having to make predictions and measuring this in lab really helped."
M.C., 4-29-85: "The labs have allowed me to be a 'scientist' a few hours a week. By playing the role of a scientist, I have been able to understand science in greater depth. One can read, do problem sets and listen to lectures and learn, but until all that knowledge we've listened to and we've read about is put into action, it really cannot be grasped to its fullest potential."
S.D., 4-29-85: "The lab on waves, where we gained experience in CREATING different waves was very beneficial to me."

Easier Learning: Concrete Lab Experiences
J.C., 4-29-85: "Using a slinky helped me to remember the difference between longitudinal and transverse waves because a slinky is such a simple common thing, which is easy to remember. I bet I would have never understood sound theories without hands-on experiments and presentations."
J.C., 4-29-85: "The small group atmosphere in lab has made it easier to understand more about waves and sound."
T.R., 4-29-85: "Slinkies helped me to understand transverse and longitudinal waves. I was able to see the different movement of the two waves. The ripple tank ... was an important visual aid. Wave properties in a ripple tank allowed you to see diffraction, interference, refraction, etc. I found the ripple tank to be enjoyable."
M.L., 4-29-85: "The resonance tube proved that there are many frequencies that are different and that waves differ in many ways because of this--There are zillions upon zillions of frequencies!! And we can only hear a small fraction of them!"

M.C., 4-29-85: "It (visual, hands-on experiences in lab) helped me understand something very abstract--by using concrete examples, it helped me see something I can't see and how it works such as sound and waves."
C.S. 4-29-85: "Seeing something is so much better than just reading about it. It seems to help it be concrete in my mind."

Small Group Environment: More Individual Involvement
J.C., 4-29-85: "The small group atmosphere in lab has made it easier to understand more about waves and sound."
P.H., 4-29-85: "Small group lab is a wonderful thing . It gives me time to hear explanations and discussions again about what was discussed in lecture. It is a great reinforcement for lecture and also provides a more relaxed setting to ask questions and get extra help. Which I always need!"
P.H., 4-29-85: "Small group lab has definitely improved my enjoyment of science. The atmosphere is relaxed, not tense, and informal--allowing for alot of open discussion and participation. I don't feel inhibited anymore to take guesses or make conclusions about what is happening in lab, because I know and feel it's okay to do so and I won't be penalized for my wrong guesses."
P.H., 4-29-85: "The only thing with lecture is that I do not feel comfortable enough to ask questions or guess. Maybe, because there are so many more people around and I don't want to hold up things or appear 'dumb'. The textbook and problem sets are helpful, but sometimes more confusing. So when this happens, I turn to small-group lab for help."
M.C. 4-29-85: "I cannot say enough about the friendly, informal, concerned lab environment. It has definitely improved my attitude about science. I look forward to lab because even though I'm discouraged at times because it's so hard for me to comprehend some concepts. But it is always comforting to know there is always someone, including the lab instructor, there to help me."
M.C., 4-29-85: "Truly, my 'scientific attitude' has 'transformed' from negative to positive because of my experience in the laboratory."
C.S., 4-29-85: "The atmosphere in the lab is helpful from the standpoint of size. I feel I get more help from the instructor than what I would get in a larger class. Every-one is on a first name basis and I think this helps keep it informal and non-threating."
B.D., 4-29-85: "The lab and recitation are helpful because it is a very friendly atmosphere. We can ask questions and not feel dumb by asking them. Also when we ask questions we don't just get the answer. We're asked to think for ourselves and guided to the correct answer."

Relevance to Daily Life

J.C., 4-29-85: "The lab on eye problems was neat because I never knew why people were farsighted or nearsighted. I even explained it to my Mom last weekend after she had been to the eye doctor for new glasses! She was so impressed. (So was I that I could apply science to everyday life.)"
T.R., 4-29-85: "Taking pictures using a regular camera I always knew light played an important part. But by using the pinhole camera, I know why some pictures are over-exposed or under-exposed and I feel I have a better understanding on how to improve my pictures. The pinhole camera answered some of my questions concerning picture taking."
T.R., 4-29-85: "Before the laboratory dealing with light I never considered light as being a wave, but I found out some fascinating facts about light. . .why shadows form. During this lab your hands were actually doing the work to form shadows. The lab allowed me to answer questions related to everyday life."
M.L., 4-29-85: "Lab not only showed me the basic concept of longitudinal and transverse waves, but it also showed me many important characteristics of waves that I'm sure will help me explain alot more things in everyday situations and class!"
M.C., 4-29-85: "Also that waves bend--this could be seen in the ripple tank--so now I can actually see how sound waves bend when my voice sounds hit a wall,etc.)
M.C. 4-29-85: "I was fascinated to understand how glasses (lenses) work and how people are far and near-sighted. By having to actually measure--move back and forth the object and lense and screen, I could understand perfectly how people see. Without this demonstration, I couldn't have understood how when focus point comes behind the retina of a person he is farsighted. Having to make predictions and measuring this in lab really helped."
M.C., 4-29-85: "All of this demonstration of color taught me tremendously. Now when I look at a tree, I know whey I see green!!"
M.A., 4-29-85: "I understood how our eyes worked and how our eye sees light. Also, I always knew what near and far-sightedness menat, but now how objects were formed in front and behind the retina, nor what glasses did to help. This lab helped explain all these things to me."
C.S., 4-29-85: "The eye problems (lens lab) were particularly interesting to me as I am near-sighted and to actually understand what is happening with the light not focusing on my retina is neat."

LABORATORY COMPARED TO OTHER COURSE EXPERIENCES
J.C., 4-29-85: "The lab experiences helped to bring together everything discussed in lecture and the chapters I read in the book. There is more hands-on in lab of course, so I think lab gives us the chance to "play around" and

figure out things by ourselves. We listen in lecture, then we get to apply in lab."
J.C., 4-29-85: "The hands-on experiments demonstrated the concepts so much better than a text book. I liked having the chance to figure out the problems by myself and with my lab partner.
T.R., 4-29-85: "I receive more from labs than lectures. I will say our lecture teacher is good, but I receive more from reading or actually having hands-on experiences. Problem sets: I feel they are just another aid in helping us to understand terms, that we are introduced to in lab."
M.L., 4-29-85: "I think refraction is something I'll never forget. When I saw the waves bend in the ripple tank, it made the picture of the dog in our book so much easier to understand."
M.A., 4-29-85: "Lab is the best part of this course. This is where I learn the most. Lecture sometimes gets boring and hard to follow. In lab I get the chance to actually see the phenomena we are discussing. These things stick in my mind and I remember them much more than a definition or an answer to a problem from a problem set. Even when Dr. ... shows an experiment I still feel like I really don't understand. I really enjoy the hands-on experience from lab."
B.D., 4-29-85: "Altogether the class has been good and I've learned alot, especially from lab experiences."
C.S., 4-29-85: "The lab is learning by doing which is a good reinforcer to me. The problem sets are helpful to a point, but it's hard to visualize some of these things from the problem sets, but lab experiments you can see."
S.D., 4-29-85: "I feel this course is set up pretty well. The labs are fun and you learn alot from them. The textbook is very easy to read and understand. The lectures are not too fast."
P.H., 4-29-85: "I feel that the lab would have to come first in improving my scientific attitude and helping me to learn (not memorize) science. . . .The lecture would be next, having super demos in class is a great addition to just teaching concepts and sure helps me alot. . . .The only thing with lecture is that I do not feel comfortable enough to ask questions or guess. Maybe, because there are so many more people around and I don't want to hold up things or appear 'dumb'. The textbook and problem sets are helpful, but sometimes more confusing. So when this happens, I turn to small-group lab for help."
M.C., 4-29-85: "The labs have allowed me to be a 'scientist' a few hours a week. By playing the role of a scientist, I have been able to understand science in greater depth. One can read, do problem sets and listen to lectures and learn, but until all that knowledge we've listened to and we've read about is put into action, it really cannot be grasped to its fullest potential."

<u>M.L., 4-29-85:</u> ". . . because I am understanding and because I can prove my understandings and test them through lab that I am a scientist . . . Sometimes lecture could be more exciting!!! Let's liven things up. . . . I like more demonstrations! Can't get enough! I think that will be important to children too! Along with hands-on lab and explanations!"
<u>S.M., 4-29-85:</u> "The laboratory experience was much more beneficial to my learning than any other aspect of the course. Lecture introduced or previewed the concepts to be learned in each unit. Lab, recitation, and the problem sets developed my understanding of each concept to be learned. And the textbook tied everything together. The laboratory expeience was also highly beneficial to developing my 'scientific attitude.' During lab, I was able to from hypotheses, test them, and develop generalizations based on the conclusions in my experiments."
<u>A.L., 4-29-85:</u> "The <u>lab</u> is <u>very</u> helpful and brings the concepts (presented through other means) into better focus."
<u>M.S., 4-29-85:</u> "I benefit most from the lab experiences, but the textbook, problem sets and lectures are also helpful. . .I enjoy lecture, especially when there are demonstrations."
<u>M.K., 4-29-85:</u> "I liked the lab better than lecture because then you get to actually do the experiments yourself."
<u>M.E., 4-29-85:</u> "The benefits of the lab experiences give a more demonstrated and clearer view of what takes place in certain circumstances. You actually see the waves in the ripple tank, and you see the mixtures of colors and what they produce and this helps you . . .so you can remember it and understand it . . .whereas the lecture should be more for definition and explaining the basics of the labs."
<u>J.B., 4-29-85:</u> "The lab makes you feel comfortable about science and learning science. You feel free to ask questions and are not afraid of being 'wrong' or appearing 'stupid'. When reading the text or doing problem sets, there is no chance for immediate feedback or help if you don't understand something. I think this is where some of the frustration comes from, but that is alleviated in the lab setting."
<u>E.F., 4-29-85:</u> "The laboratory is good for its practical application of the concepts we are dealing with in class. It is a much different matter, hearing about certain phenonenon compared to seeing it demonstrated. The lab is beneficial for the latter, the lecture primarily for the former. Each aspect has equal merits."
<u>C.H., 4-29-85:</u> "I would say the lab has been the most helpful but lectures (demos) definitely give them a close race."
<u>D.H., 4-29-85:</u> "If it wasn't for the lab activities, I would be lost. The text is a good book, but it is also confusing sometimes. The labs help to clear up terms and certain theories. The lectures are also helpful, but the

labs seem to bring everything we have been talking about together."
M.M., 4-29-85: "the benefits of the lab helped to tie in all aspects of the class including the book, problem sets and lecture."

COMPARISON WITH OTHER CLASSES, SCIENCE METHODS, ETC.
M.C., 4-29-85: "I must say I have never experienced a class where the professor and lab instructors, are so willing to help and even go out of their way to help you understand the new concepts."
M.C., 4-29-85: "The whole class is a very friendly and warm atmosphere and the instructors are to be commended for this--because I feel in most departments this is very rare! I felt I needed to mention this so that the instructors will continue to do as they are doing in the future."
M.A., 4-29-85: "I really enjoy lab. This is my first lab experience where I've known what I was doing and didn't feel lost. Also, the labs deal with lecture which I like alot."
CLASS DESIGN:LABS,LECTURES,ETC.,COMPLIMENTARY & REINFORCING
J.C., 4-29-85: "The lab experiences helped to bring together everything discussed in lecture and the chapters I read in the book."
P.H., 4-29-85: "It (lab) is a great reinforcement for lecture and also provides a more relaxed setting to ask questions and get extra help."
P.H., 4-29-85: "Both (lenses & colors) help to give visual images of several concepts taught in lecture and it lets us apply and experiment with these concepts to see if they were correct."
M.A., 4-29-85: "I really enjoy lab. This is my first lab experience where I've known what I was doing and didn't feel lost. Also, the labs deal with lecture which I like alot."

SUGGESTIONS FOR IMPROVEMENT
M.L., 4-29-85: "Sometimes lecture could be more exciting!!! Let's liven things up. . . . I like more demonstrations! Can't get enough!"
M.A., 4-29-85: "Lecture sometimes gets boring and hard to follow. Even when Dr. ... shows an experiment I still feel like I really don't understand."

SPECIAL RESEARCH EXERCISE:

LABORATORY EXPERIENCES: SUMMER 1985

UNDERSTANDING OF WAVES: SOUND AND LIGHT

L.S., 7-8-85: "I discovered many things about my eye condition (lens lab) that really helped me understand my problem. I'm both far-sighted and near-sighted because of the severity of my astigmatism. I not only need a convex lense, but also a concave lense."
L.S., 7-8-85: "Color pigments and their relationship to color primaries is now much clearer."
P.P., 7-8-85: "The ripple tank was also fun because we could manipulate various aspects of it and see the different effects caused by our manipulation. It demonstrated and helped me understand the phenomena of diffraction, refraction and reflection, and the effects of constructive and destructive interference."
B.DEL., 7-8-85: "The best demonstration of longitudinal waves was the long suspended slinky which periodically contained white balls. These procedures always come to mind as we later built on the wave theory."
B.DEL., 7-8-85: "The resonance tubes contribution to me was to verify the speed of sound, making something abstract become a real and measurable entity. This fact, in a way, helped me to visualize light and the speed of light in a similiar manner (although it is beyond my ability to measure). Anyway it helped me with my mental picture of light as something which travels at some measurable speed."
B.W., 7-8-85: "When you are in lecture and the prof is talking about transverse and longitudinal waves, it is hard to understand what is meant by something being at a right angle to some direction. But when you get into the lab, and use a slinky to make the different kinds of waves, it's a big help. If we did not have the opportunity to use the slinky, I still might not understand the difference between transverse and longitudinal."
P.C., 7-8-85: "Small group and lab activities have helped quite a bit when it comes to understanding waves. When I first looked at examples in the book about waves types, I was somewhat confused. The lab exercises using the slinky helped me to understand this better, because I actually saw it moving right before my eyes. In the book, one has to imagine."
B.D., 7-8-85: "Until I actually shook the slinky I didn't really get (understand) wave motion."

EFFECTS ON ATTITUDE

Good Role Model: High Teacher Concern

L.S., 7-8-85: "The personal attention that I've received has probably been one of the greatest influences on my

desire to achieve and do well in the course. I feel that my instructors care how I do and therefore I have felt the desire to put forth extra effort and do my very best."

C.H.C., 7-8-85: "The attitude of both teachers tells me that they want their students really to learn the concepts, and they want us to see how important science is in the elementary classroom and how easy it is to do."

S.G., 7-8-85: ". . . the instructor is always sure to let the class know that he'll stay after with anyone who needs more time and/or help. . . It instills a desire to experiment and learn with each other."

P.L., 7-8-85: "Individual help was offered even though I didn't take advantage of it. I was pleased to find that there was much concern in actually understanding the material. Most instructors don't really care, except for this class."

B.W., 7-8-85: "Also being able to have a teacher help you personally on a one-to-one basis is very important. If there was no teacher able to walk around and help, the course would be a lot harder because you would be left by yourself to try and understand the concepts."

B.D., 7-8-85: ". . . very personal approach in lab has been extremely helpful and encouraging. His sense of humor, straightforwardness and consideration of students encourages the asking of questions. . . He makes learning non-threatening."

Less Anxiety, More Enjoyment, Confidence in Teaching

L.S., 7-8-85: "I found that the individual attention and the informal atmosphere helped to ease my fear of 'physics'. I came into the class with dread and a real paranoia about it. However, I feel the concern on the part of the instructors has been especially friendly and helpful."

K.D., 7-8-85: "The small group lab has also taken much of the pressure off and I have found I am beginning to enjoy it. Before I came into the class I was very scared! I knew nothing about physical science and I just knew I wasn't going to understand anything. But to my pleasant surprise, I am finding that is not true and I know half of it rests on the fact of how the class is conducted."

C.H.C., 7-8-85: "My 'scientific attitude' has improved, and I feel more comfortable about using it in the classroom; I think I can make science fun and relative to the student's world for a more meaningful experience, which promotes long-term learning."

B.DEL., 7-8-85: "This lab (pinhole camera) was one of the most enjoyable and memorable classes of my college experiences. I am definitely going to make this a part of future curriculums in my classes."

J.P., 7-8-85: "I want to stress that although I do not typically enjoy a 'lab situation', I am grateful for this one. It made the concepts 'real' and understandable. . .

It has made me much more open to science and much more accepting to teaching it and really becoming involved in it. I do want science to have an important place in my classroom--these lab activities have helped form that desire."

J.M., 7-8-85: "I began to enjoy science which is normally my least favorite subject. . . Lab makes science seem to be for anyone. It puts science within reach and makes it fun for people which makes it more enjoyable."

S.B., 7-8-85: "It (lab) gives me different styles to approach the material from. Lab times are fun times also, where the pressure is somewhat off and you are free to inquire and experiment, challenge, make mistakes and do over again. It is an atmosphere where I have the time to sit back, look at the material and see for myself how it all fits together and works."

C.B., 7-8-85: "The small group lab has improved my enjoyment of learning science in that I was able to ask my peers questions and adjust the pace if we did not understand what was going on. Even though the instructor may not have been available to answer questions, my peers (some) were happy to take the time to explain concepts to me. I feel that I really enjoyed science since I could help others which enhanced my understanding and helped my enjoyment of the class. I wass not afraid to ask questions since many in my group had the same questions."

P.C., 7-8-85: "Not only was it fun, but it was also exciting and educational to learn how light and cameras work. This was beneficial to learn, for it helped us to understand how much in common cameras have with our own eyes."

P.C., 7-8-85: "The lens lab helped me understand what was actually wrong with my own eyes. . . Being that this was such a personal basis to me, I believe I learned quite a bit. Now when one of my young students must come to wearing glasses, I may be able to help this cahild accept the fact by explaining some of the things I have learned in this class."

M.C.M., 7-8-85: "I have always had a bad attitude towards science. . .I was very nervous about taking this class . . .I knew it would be a struggle. . . Hands-on experience in the small-group have been very helpful in clearing up some of this confusion. I seemed to understand the concepts much better after seeing them actually happen."

EFFECTS ON LEARNING & TEACHING

Good Role Model: Teaching Techniques and Resources

L.S., 7-8-85: "I think the analogies used in lecture and lab were well placed and complimented the subject. Everyone of the examples and analogies related to, and helped explain, the topics being covered. There was always an open and helpful atmosphere in both lecture and lab. I always felt that if I were to have a question or need assistance, someone would gladly help. Questions were welcome and encouraged. . . They helped in solving problems using the understanding of a subject rather than the simple memorization."

K.D., 7-8-85: "I am excited about teaching these units in a classroom. . . I have at least a half year of science units with experiments for my students. My future students and I will all benefit from this class."

C.H.C., 7-8-85: "I like the idea of doing experiments first so that students can discover for themselves and get their own idea about a concept first. . . It is also good that students are allowed to predict, without fear of being wrong."

C.H.C., 7-8-85: "In the lab sessions we could get together with fellow students and hear each others ideas. I feel sure there is always time for questions, and I like the way the instructor is always going from table to table helping and talking. I think it is important to have both lab and lecture because it provides an opportunity for students with different 'learning styles' to learn, and not be left out."

B.DEL., 7-8-85: "This lab (pinhole camera) was one of the most enjoyable and memorable classes of my college experiences. I am definitely going to make this a part of future curriculums in my classes."

B.DEL, 7-8-85: "I cannot say enough good things about the way lab is run. The pace is crisp, well-organized and to the point. Everyone is involved and the instructor is genuinely concerned that each student understand all the concepts which are presented."

B.DEL., 7-8-85: "Predicting ray paths and testing predictions is an effective teaching methods, (even if your prediction is incorrect, the act of correcting makes the final result more memorable."

J.P., 7-8-85: "I also really liked the fact that so many of the activities were applicable to our future elementary teaching."

S.B., 7-8-85: "We worked as a group and this acts as a self-teaching element I think. . . . You get a look at a situation from 4-5 different sets of eyes and interpretations. That way you rule out one set answer or you at least think about some other views. This provides for a overall learning environment and not just a teacher directed learning situation. We learn from the teacher, ourselves and observations, others' observations, ontributions and we can make mistakes and discover new things or anothe aspect of the same situation."

P.C., 7-8-85: "I was so pleased with this lab exercise (ripple tank), that I am sure that I will use it with my students some day. I am sure that it will show properties of waves as clearly to them as it did for me."

Scientific Processes: Activity Oriented Skills

L.S., 7-8-85: "I found that the small groups helped because they allowed everyone to get involved. Everyone in the group got a chance to participate in the experiments and see cause and effect... By trial and error we learn and by adjusting the height of the tuning fork, I discovered the natural frequency of the resonance tube."
K.D., 7-8-85: "Be being able to do it myself I could experiment with those ideas and formalize in my mind what was actually taking place in the properties of a wave. It also helped me to rememberand apply it to other situations."
C.H.C., 7-8-85: "I like the idea of doing experiments first so that students can discover for themselves and get their own idea about a concept first. . . It is also good that students are allowed to predict, without fear of being wrong."
P.P., 7-8-85: "The ripple tank was also fun because we could manipulate various aspects of it and see the different effects caused by our manipulation. It demonstrated and helped me understand the phenomena of diffraction, refraction and reflection, and the effects of constructive and destructive interference."
B.DEL., 7-8-85 "Predicting ray paths and testing predictions is an effective teaching methods, (even if your prediction is incorrect, the act of correcting makes the final result more memorable."
S.G., 7-8-85: "I often need to be able to observe and manipulate objects in order to understand the meaning behind phenomena."
S.B., 7-8-85: "When you have to create the situation yourself, it means alot more and sticks with you a lot longer. Doing helps you really remember it and not just memorize it like you would be doing with just a lecture. Lectures alone aren't as applicable."
S.B., 7-8-85: "I would have had a hard time believing that magenta and green would make white, but when you do it, there is no doubt left in your mind and because you've seen it, it's much easier to remember."
S.B., 7-8-85: "It (lab) gives me different styles to approach the material from. Lab times are fun times also, where the pressure is somewhat off and you are free to inquire and experiment, challenge, make mistakes and do over again. It is an atmosphere where I have the time to sit back, look at the material and see for myself how it all fits together and works."
P.L. 7-8-85: "I enjoyed the lecture alot. It helped me to learn the basics of what was being taught. However, more individual attention was given in lab where the experiment supplemented the lecture. Doing and seeing or observing is better than just listening."

Easier Learning: Concrete Lab Experiences

L.S., 7-8-85: "Without such visual aids (lab experiments) I would have to try and imagine the experiments and the results."
L.S., 7-8-85: ". . the pinhole camera was the most informative. . due to the fact that I was very involved with the lab and found it interesting."
K.D., 7-8-85: "By having these hands-on activities during the sound unit it certainly made those concepts easier to understand."
K.D., 7-8-85: "I am not as apt to forget the concepts if I have first-hand experiences that I can recall and relate to."
P.P., 7-8-85: "I liked the resonance tube because, resonance was a term I had heard and occasionally used but after working with it in lab, now know what it is and does."
B.DEL., 7-8-85: "I am a visual learner and recognize the value to me of the 'hands-on' type of lab--so far it has been my salvation in understanding the concepts set forth."
L.E., 7-8-85: "Working through the labs finally got me to understand the principles behind them (the concepts.)"
S.B., 7-8-85: "Lab helps to connect the material. Instead of just learning about cameras outright, lab provides the opportunity to work into the concept by defining terms and properties while doing.
B.W., 7-8-85: "When you are in lecture and the prof is talking about transverse and longitudinal waves, it is hard to understand what is meant by something being at a right angle to some direction. But when you get into the lab, and use a slinky to make the different kinds of waves, it's a big help. If we did not have the opportunity to use the slinky, I still might not understand the difference between transverse and longitudinal."
B.D., 7-8-85: "Until I actually shook the slinky I didn't really get (understand) wave motion."
S.V., 7-8-85: "Listening and watching is not the same as actually doing."

Small Group Environment: More Individual Involvement

L.S., 7-8-85: "I found that the small groups helped because they allowed everyone to get involved. Everyone in the group got a chance to participate in the experiments and see cause and effect... By trial and error we learn and by adjusting the height of the tuning fork, I discovered the natural frequency of the resonance tube."
K.D., 7-8-85: "The small group lab has also taken much of the pressure off and I have found I am beginning to enjoy it. Before I came into the class I was very scared! I knew nothing about physical science and I just knew I wasn't going to understand anything. But to my pleasant surprise,

I am finding that is not true and I know half of it rests on the fact of how the class is conducted."

P.P. 7-8-85L: ". . .you can discuss what you are doing with your partners. I felt more comfortable saying that I didn't understand what was happening so it was easier to work in this small group."

B.DEL, 7-8-85: "The 'work together, help each other and get to know your class mates' approach creates a very comfortable and unthreatening atmosphere in which to work."

S.G., 7-8-85: "In this lab the atmosphere is so informal that I don't consider my classmates as 'lab partners'. Instead, I've met some new people, made some new friends. These are friends who are willing to work with me, help me, and seek my advice and help. . . At the same time we laugh and joke and have fun with the experiments. . . Working in groups gives me more resources to turn to if I need help."

L.E., 7-8-85: "Having a small number at each lab table has enabled us to . . become familiar enough with each other to admit when we are confused. It also helps to have more than one explanation for the same thing. That way you get many perspectives of the same concept."

S.B., 7-8-85: "The small group lab experience has improved my enjoyment of science immensely. . . What one person is lacking, another person's contribution will make up for. This really reduces the risk of failure in the setting. It makes it a much easier setting to learn. It's like having a consultant, tutor, advisor, encourager, etc., right in one group. I really like that and I've learned so much from my group members. It takes (away) the stereotypic 'seclusion' from the term science."

C.B., 7-8-85: "The small group lab has improved my enjoyment of learning science in that I was able to ask my peers questions and adjust the pace if we did not understand what was going on. Even though the instructor may not have been available to answer questions, my peers (some) were happy to take the time to explain concepts to me. I feel that I really enjoyed science since I could help others which enhanced my understanding and helped my enjoyment of the class. I wass not afraid to ask questions since many in my group had the same questions."

Relevance to Daily Life

L.S., 7-8-85: "One of the most important labs for me was the lenses lab. I found this true because of my very poor eyesight. I discovered many things about my eye condition that really helped me understand my problem. I'm both far-sighted and near-sighted because of the severity of my astigmatism. I not only need a convex lense, but also a concave lense. This is all extremely informative and interesting to me especially because of the personal identification with it."

K.D., 7-8-85: "I find myself excited by the new found knowledge. I even try some of the concepts in application in my everyday world."
C.H.C., 7-8-85: "The lense and the eye problems was a very important lab, too, because I think it is important for teachers to understand eye problems so they can show students exactly why some of their classmates are wearing glasses. This way I don't think the students will get teased as much because everyone will understand why their eyese are different, and they will also understand how light is effected by lenses. I think it is more meaningul when a concept can be made relative to a student's world."
B.DEL., 7-8-85: "The wave tanks were excellent for visualizing wave phenomena (diffraction, refraction, reflection, and interference). . . This past 4th of July weekend I spent at a small lake near Lake Michigan. My family learned quite alot about wave phenomena."
B.DEL, 7-8-85: "I was very interested in the section on far and near-sightedness--these are terms everyone uses, but few can actually explain. . . rainbows were similarly interesting. I have already enlightened my wife in this regard and she was very impressed now whe thinks I'm smart!"
S.G., 7-8-85: "The lab on far and near-sightedness was very valuable to me. I am near-sighted, but until the lab, I never knew the reasons why."
S.S., 7-8-85: "I feel that these labs are very beneficial . . . The waves are a phenomena I knew about and enjoyed (I love spending time watching waves and water flow), but getting the hands on experience of manipulating . . you gain a new insight into understanding what is really happening."
B.W., 7-8-85: "Being an eye glass wearer, it was interesting to find out what was happening in my eye and how it was corrected. I never knew that concave and convex lenses were used for the glasses to correct eye problems."
P.C., 7-8-85: "Not only was it fun, but it was also exciting and educational to learn how light and cameras work. This was beneficial to learn, for it helped us to understand how much in common cameras have with our own eyes."
B.D., 7-8-85: "His explanations are particularly helpful when he makes science connect with the rest of life--our future classrooms, . . or something we can relate to. When he makes an effort to know the students, he has a handle on how to work in relevant examples."
M.C.M., 7-8-85: "Never before had I really understood this process of the eye. I had not really understood why I could not see as well either. It was quite informative when I was able to put my own glasses in place of the lenses already there. Then I was able to see why my glasses were made the way they were and also what exactly was wrong with my own eyesight."

LAB COMPARED TO OTHER COURSE EXPERIENCES

P.P., 7-8-85: "The labs were good because of the hands-on experience and being able to see and observe what was being discussed in lectures. I was able to understand better what I was reading and what lecture material we were covering."
P.L., 7-8-85: "Laboratory experience was the most helpful in developing a 'scientific attitude' and learning science. The reason is because of hands-on experience and actually performing the experiments. The textbook was helpful when looking up definitions and when going more into detail, but I feel that I learned more when actually performing the experiments. I enjoyed the lecture alot. It helped me to learn the basics of what was being taught. However, more individual attention was given in lab where the experiment supplemented the lecture. Doing and seeing or observing is better than just listening."
B.W., 7-8-85: "I think the lab portion of the class is the most helpful. You get hands-on experience to learn what was talked about. The lecture is important, too, but the lab . . brings everything together."
C.B., 7-8-85: "The lab experience allows a student (me) to actually manipulate and control the lab experiments. The textbook didn't allow me to see concepts in action. The same with problem sets and lecture."
P.C., 7-8-85: "the lab has helped me in developing a 'scientific attitude' by tieing everything together."
B.DEL., 7-8-85: "Lab is the number one vehicle to development of a scientific attitude. When you observe a phenomena and must describe it and draw conclusions, you observe closely and try to be objective and precise in your conclusions."
S.G., 7-8-85: "The lab offers expansion on the text, problem sets, and lectures. The labs are very well matched to the other portions of the course. . .The labs expand on the terms and topics covered in the text."
M.C.M., 7-8-85: "I think the number one benefit of the lab experience is the hands-on experience. In comparison to the book, lecture, and problem sets, the lab allows me to really see the concepts into action. I think if someone would have told me that red and green make yellow, I would have had a harder time believing them if I was not able to do it myself."
L.E., 7-8-85: "I think the lab is a great 'hands-on' experience. I do feel people can learn from lectures, text, and other teacher-directed activity, but there are many who need to 'do' before they can learn completely what generalization is being taught. I feel that if there is any misconception about the material in lecture, it will be caught in lab. Thus it is a great chance to reinforce idea and clear up misunderstandings."
B.D., 7-8-85: "The laboratory experience has the major benefit of keeping me in class. If all we had were

lecture, textbook, and problem sets, I probably would have forfeited my tuition expense and stopped coming. The only attitude I would have gained concerning science is a renewed fear and dislike. . .I have come a long way toward opening my mind enough to explore science."

S.B., 7-8-85: "Instead of taking in the information and acting like a sponge in the (situations other than lab), I can recall the information, and through a hands-on experience, apply it. . . Lab is more of the active part of the process and an essential element in creating a scientific attitude."

S.B., 7-8-85: "I also like this time for answering questions. I would never ask a question in lecture just because the setting is much more structured, larger, etc. Lab is a more designated inquisitive time and it seems more natural to ask questions

S.S., 7-8-85: "I feel that the lab is the backbone of this class. I learn how to apply what is stated in the text and lectures. The informal small groups only help to strengthen the learning facilitated by the lab."

COMPARISON WITH OTHER CLASSES: SCIENCE METHODS, ETC.

L.S., 7-8-85: "I don't think I can begin to express how much more I've enjoyed this physics class in comparison to other science related courses I've taken. I found that the individual attention and the informal atmosphere helped to ease my fear of 'physics'. . . The thing which really impressed me the most was that they knew my name and used it. In such a large university, you have a tendency to become lost in a sea of faces and numbers."

K.D., 7-8-85: "I think by doing hands-on experiments, I am more able to apply my new knowledge. Where perhaps if I had not been able to see and do first-hand, I would still be at the stage of regurgitating vocabulary and stated concepts."

C.H.C., 7-8-85: "It all shows me that both teachers really care about us learning the concepts, and not just the memorization of facts."

C.H.C., 7-8-85: "I think it is important to have both lab and lecture because it provides an opportunity for students with different 'learning styles' to learn, and not be left out."

B.DEL, 7-8-85: "The 'work together, help each other and get to know your class mates' approach creates a very comfortable and unthreatening atmosphere in which to work. I think this approach should be carried on in other areas besides science--whenever the subject matter will allow it and at all levels of education."

B.DEL., 7-8-85: "I have never had the feeling that we, as students, were being 'talked at' by the instructors. Everything is conducted with dignity and respect--even those

'dumb' questions or responses that one would ordinarily surpress."

J.P., 7-8-85: "I want to stress that although I do not typically enjoy a 'lab situation', I am grateful for this one. It made the concepts 'real' and understandable. . . It has made me much more open to science and much more accepting to teaching it and really becoming involved in it. I do want science to have an important place in my classroom--these lab activities have helped form that desire."

P.L., 7-8-85: "Individual help was offered even though I didn't take advantage of it. I was pleased to find that there was much concern in actually understanding the material. Most instructors don't really care, except for this class."

P.C., 7-8-85: "I have not had so much opportunity for outside help in a long time. I sometimes feel guilty that I do not take up on this offer as much as I should. This, among all other things mentioned, has helped me to enjoy science much more."

CLASS DESIGN: LABS, LECTURES, ETC., COMPLEMENTARY AND REINFORCING ASPECTS

L.S., 7-8-85: "The thing I liked best (about the lab experience) was the way everything seemed to interact and each lab built on the previous one."

K.D., 7-8-85: "But by the end of the unit session between the lectures, lab, write-up, problem sets and individual help it becomes much clearer and pretty much understandable. All the methods for me build upon each other and seem to be doing a successful job."

K.D., 7-8-85: "I have found labs reinforce different concepts . . and make applications much easier."

C.H.C., 7-8-85: "I think it is important to have both lab and lecture because it provides an opportunity for students with different 'learning styles' to learn, and not be left out."

P.P. 7-8-85: "This type of laboratory was helpful because I was able to observe up close the phenomena that was being discussed and demonstrated."

B.DEL, 7-8-85: "I cannot say enough good things about the way lab is run. The pace is crisp, well-organized and to the point. Everyone is involved and the instructor is genuinely concerned that each student understand all the concepts which are presented."

S.V., 7-8-85: "Without the very good organization and coordinating of lecture and lab by the instructors, this class would really be a mess with all the material to cover. This plus the way it is presented, has led to more enjoyment of science."

SUGGESTIONS FOR IMPROVEMENTS

P.P. 7-8-85: "I think a little more time is needed to discuss some of the labs as a whole class. . . like some of the color lab."

APPENDIX B: ETHNOGRAPHIC DATA

The following collection of student quotes are referred to in this research as "Ethnographic Data". Included in the "Ethnographic Data" appendicies are student quotes from "The Special Research Exercise", "Interviews", "Transfer of Learning/ Teaching Skills", and "Anonymous Quotes". Quotes are divided into separate sections for Spring term and Summer term.

Appendix B refers only to the Interviews. The Interviews were conducted in the last half of each term. The type of questions were primarily open-ended and were asked in three areas of concern. The first area of concern was with possible changes in student attitude toward science and science teaching. The second area of concern was with possible changes in their knowledge of science and its relationship to their personal experiences with this course. The third area of concern was with the students' change in their science-learning skills and their evaluation of different science-teaching skills.

Pretest surveys, pretest questionnaires, The Special Research Exercise (appendix A) and student responses during the Interviews served primarily as an Interview Guide.

CATEGORIES FOR INTERVIEW QUOTES

<u>CHANGE IN ATTITUDE</u>
Student quotes: Spring term, p. 204; Summer term, p. 211

<u>CHANGE IN KNOWLEDGE</u>
Student quotes: Spring term, p. 207; Summer term, p. 214

<u>CHANGE IN LEARNING/TEACHING SKILLS</u>
Student quotes: Spring term, p.209; Summer term, p. 215

INTERVIEW QUOTES: Spring 1985

CHANGE IN ATTITUDE:
I.B., 5-1-85:
INT: "What in your past experience has contributed to your high anxiety towards science?"
I.B.: "I was very frustrated in elementary school. I wasn't able to focus on what ideas were and put them down on paper. In 7th and 8th grade science, we had ... a big class,so teacher did experiments in front of class without participation. Very boring to me. I could see what was going on, but was frustrated because I couldn't understand what was going on and felt I couldn't ask an intelligent question. At times, it was interesting--at times it wasn't."

"In high school I had 2 years of science and then chemistry and biology was required--it just didn't stick with me. I remember being very frustrated throughout. In biology,we didn't have many lab activities and concentrated mostly on book material--only a couple of experiments per term. In chemistry, we did more labs and it made it more enjoyable and easier to grasp. we had a good professor and he made his own homemade projects and brought them in."

"In high school physics, it was all book and all math equations. I didn't like it at all and got a poor grade. In college natural science course, we memorized what we read in the book -- large class. We did have recitation and some experiments, but no labs, I somewhat enjoyed it."

"On the first day of class, I approached you and Tom and told you that I was really paranoid about taking this class. That went down because of your attitude. You love what you're doing and are constantly here helping all of us and that gave me alot of self-confidence. I feel that I can ask the same question 5 times. In other classes I had felt that I couldn't do that."

"My past experience in science was negative because I was frustrated with books which were used and lack of hands-on experience. This class stresses learning first and then grades. Tom and Jim motivate students to learn and enjoy. Positive outlook. I actually feel confident in teaching science now."

"I can not only apply the science I learned, but reflect a positive attitude toward what I teach." INT: "You mean the techniques we give you and the type of environment we try to generate?" I.B.: "Yes, that's very important especially in a subject like science because you have to be able to apply what you're learning. In social sciences, it's much easier."

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M.C., 5-1-85:
INT: "What in your past experience contributed to your high anxiety towards science?"
M.C.: "I didn't like high school chemistry and biology. It may have been the instructors. It wasn't a fun experience, not many labs. Junior high science was all textbook, no labs. I enjoyed college biology and did real well, enjoyed labs. No demos in lecture, but did have film strips." My anxiety has decreased since taking this class. It has been an enjoyable experience."

"The atmosphere of class improved my understanding and attitude. I looked forward to lab. Always someone to help. Enjoyed the atmosphere--certain level of comfortableness. Unfortunately, in other classes, I hadn't found the friendliness and helpfulness, going overboard to do it. I am a senior and have taken alot of classes."

D.S., 4-24-85:
"My anxiety towards science is high because I didn't have that much exper- ience with science in high school or prior to high school. The classes I had were not successful as far as what I retained in them. In junior high science, it was lectures and some films--no labs. I only enjoyed one unit on the planets."

"College biology was hard for me because it moved too fast--didn't want to tell them to slow down... since taking this class, my anxiety has gone down a little bit. Sometimes I feel lecture is too fast, but I'm enjoying labs more than I thought. I feel more confident in my ability."

P.H., 5-2-85:
"My anxiety towards science was fairly high before taking this class. In high school science classes,I never really tried hard--never felt getting much out of class. Science was a goofing off class,not enough structure... There were alot of labs in them, but no direction as to purpose of labs. No follow-up to see if you understood. Class atmosphere was fun time. Instructor did come around to see how we were doing."

"In 1st term college natural science, I did all right and enjoyed it; 2nd term was confusing, rushed, didn't care for it; 3rd term was the most boring, no lab work, more discussion, didn't get proof through labs and I did poorly. Since this class , my attitude has improved, like to talk to friends about class. I am still a little nervous, not 100% confident, but my enjoyment level is more."

"I put off taking this class--didn't want to take science. Glad I did now. I really want to learn now. Class is meeting my expectations. Class atmosphere is relaxed--can enjoy oneself, not stuffy."

M.S., 5-3-85:
I: "What contributed to your high anxiety towards science?"
M.S.: I haven't enjoyed science in the past. I had one high school class in biology and one 12 years ago in college. Not knowing anything about science contributed to my anxiety. I almost walked out on 1st lab. I couldn't believe I didn't know anything and decided to drop it and take it another time, but I stuck with it."
INT:"Did anxiety change?"
M.S.:"Yes, especially since I got 2nd test back and I realized I could do it. . ."
INT:"What's been beneficial in decreasing anxiety and increasing your confidence?"
M.S.:"Labs. I couldn't just get it from lecture. Small labs and extra help."
"The lab is especially helpful. I'm enjoying science for the first time.
I look forward to lab. I am a little shy--feel comfortable with a small group. Tom's enthusiastic and makes it enjoyable. I am able to ask questions."

S.D., 5-2-85:
INT: "Why do you have anxiety about science and taking physics?"
S.D.: "In high school I just had biology for 1 year. I liked it and enjoyed the 2 or 3 labs in it. In 7th grade, I only had life science and didn't have much science in grade school. I liked college geology alot--we had labs. My anxiety has gone down since taking this class. . . I am not as afraid of science. I am enjoying this class, learning something I didn't know --I see I can do it. I have developed more confidence to learn science.. . I haven't liked labs in the past because I didn't have much help or know how to do it. But I'm liking this one a little better because we have help and enough time to complete lab"

M.A., 5-6-85:
INT: "What is the source of your anxiety towards science?"
M.A.:"In elementary school, we read units out of book in science and watched teacher do experiments. it wasn't much fun, not much to remember.in high school, I had a bad science program. Teachers were bad. In labs, for example, we would measure weight of metals, then rest of lab we would do whatever we wanted to. In college chemistry, I hated tapes. I couldn't understand anything from them and I had bad background. I didn't know anything. College biology was a disaster--too hard. Labs were totally unrelated to lectures. In college astronomy, I had an interesting teacher, but he had a poor attitude. It was his first year of teaching and he was unsure of the knowledge. He told the class: 'I am going to make it hard for you.' his were the hardest tests I've ever had here--no way I could have prepared for them. I learned stuff from it, but

makes you scared to do something else. I have never had physics before."

"My attitude towards science has changed alot from taking this class--alot better; understand the book, understand the lecture. The lab ties everthing together perfectly. Now I know better what Dr. .... was explaining in lecture and what book was saying. I'm really comfortable. I like the coordination between lab and lecture."

S.F., 5-6-85:

INT: "Why do you have high anxiety towards science?"
S.F.: "In elementary school, I didn't have a strong science program. In junior high when I was introduced to it, I didn't feel comfortable with it because I was not familiar with it. In high school, I just took the minimum--9th grade exploratory science--physical science and earth science--no labs at all; In first half of biology, it was alot of chemistry--did really bad--not much lab. In second half, we did alot of dissections. I loved it and did really well. I really liked the lab. In college I took nutrition and two natural science courses--one had labs and the other didn't."

INT: "Had this class reduced your anxiety?"
S.F.: "Yes, decreased it in some ways, just hands-on labs help. Being able to do something I read about. repetition is good--reading and experience."
INT: "Was the pace of the ripple-tank lab too fast for you?"
S.F.: "Sometimes--but I think it was easy enough for me to just ask...or when you were working with us, I'd get a strange look on my face and you'd go back over it (information). I always felt free to ask questions."

CHANGE IN KNOWLEDGE:
I.B., 5-1-85:
"The lab and hands on experiments made science alot easier to understand."
"The lab experience is an 'aha' experience for me. When I can't interpret diagrams in the text, I am able to see it in lab, e.g., ripple tank."
M.C., 5-1-85:
"The hands-on, visual, small group gives you a whole new understanding about waves and sound. I had very little knowledge before. I enjoyed slinkies; ripple tank was an excellent way to see wave movement. You couldn't visualize sound waves and how they refract and diffract and interfere if it weren't for the ripple tank. I could see the words diffraction and refraction come alive when we did ripple tank."

"What I liked about lab was that it allowed me to do it so I truly comprehended what I read about. By observing, predicting and experimenting, I realize that it's not as difficult as I thought it was."
"I am able to relate what I've learned to outside experiences--know why sky is blue, grass is green, how i see the tree, how sound travels from passing bus to me. before I didn't know."

"What surprised me most about waves is that waves make the medium move and not the medium itself that's moving. What I mean is that everything seems to be an illusion, opposite of what you think it is."

D.S., 4-24-85:
"The lab is beneficial as compared to other science classes without lab. The visual aids help me alot and the lab reports give me a better understanding of terms."

P.H., 5-2-85:
"Although the demos in lecture are beneficial, sometimes the lectures are confusing--too much material. The labs are the most beneficial part of this class because we can talk about them more. The small groups in lab are good and so is the attention from the teacher... Also the hands-on lab experiences help alot because I can look at it as long as I want."

M.S., 5-3-85:
"I never could have understood waves without lab. I liked creating waves myself, e.g., ripple tank, slinky. The lab also helped me understand light. I felt I could ask questions I had to ask. I learn best 1 to 1, not in large groups."
"Lab enhances what I learned in lecture. I need both.

S.D., 5-2-85:
"My anxiety has gone down since taking this class. . . I am not as afraid of science. I am enjoying this class, learning something I didn't know --I see I can do it. I have developed more confidence to learn science."

M.A., 4-29-85:
(RE: LABS):"Reading isn't enough... Labs give me a clear idea in my mind. From ripple tank experiment in lab, I know what it looks like in my mind. It helps me retain it--from having the visual experience... I really like this aspect."

S.F.,, 5-6-85:
INT: "Have you been able to relate class to outside experience?"

S.F.: "Constantly. The first two weeks of class when I was reading about waves, it made it seem like everything in the world is somehow related to waves. So anything that happened I would find myself talking about that or joking about it. My friend is really into science and understands alot more about it."

CHANGE IN LEARNING/TEACHING SKILLS:

I.B., 5-1-85:
"I am amazed by the things I learn in class which I can relate to outside experiences such as blue skies and red sunsets, diffraction of waves on lakes. I didn't think about these things before. When a child comes to me in class, I'll feel more confident."

"I will teach by showing a child rather than telling him because of my experience of this helping me."

"As my anxiety towards science has gone down from having this lab, my confidence in learning science has definitely gone up."

"Another benefit of the lab was enthusiastic teachers like you and Tom. You emphasized the fun of science--made me curious--where light comes from, how we hear things."

"The lab was the most beneficial part of the course. The recitation and lecture complimented it nice---seems very organized, compared to past classes."

"Things weren't just brought up once, but many times. I feel that I'll remember alot and be able to apply it in my teaching. I could modify what's been done or keep it at the same level--I feel very confident about teaching science now"

M.C., 5-1-85:
"The lab helps me understand science, playing the scientist, having to do it, observing. Also instructors make things clear. It has increased my confidence in learning science. Also, has increased my confidence in teaching science. I have a little bit of knowledge so that I can do science projects with students. I can use the pinhole camera, ripple tank, the colored light demo in my teaching."

"If I didn't have a ripple tank in my class, I could set up something simpler like a dish. It would be useful for a child to see how a wave moves and then could apply it to a sound wave."

"I feel more confident than before as far as teaching science and feel alot more competent about waves and sound and that when you teach some of these, you'll learn more about it which is natural."

D.S., 4-24-85:
"I feel more confident in teaching. The ripple tank and slinky could be used. My students can have fun and learn from them, too."

P.H., 5-2-85:
"I want to use hands-on approach when I teach science. Get kids to try different ways, discovery."

"Since this class, my confidence in learning science has gone up. I now feel capable of doing it. I felt stupid before that (this class) I didn't have it in me to learn science. Also, I am definitley more confident in teaching science."

M.S., 5-3-85:
"I will use ripple tank and slinky in my kindergarten teaching. I will use a little bit of it at a time, with small groups. I feel more competent after taking wave unit because I learned so much just in 3 weeks. Demos and labs helped most and I will use some demos with my students."

S.D., 5-2-85:
"I am enjoying this class, learning something I didn't know ---I see I can do it. I have developed more confidence to learn science.... I haven't liked labs in the past because I didn't have much help or know how to do it. But I'm liking this one a little better because we have help and enough time to complete lab"

M.A., 4-29-85:
"I've developed confidence in my ability to learn and teach science. I like the way you walk around class--'ah, this is a great way to teach.'. .
I can really use the labs in my teaching. I can get them or make them, e.g., the slinky. In biology, I couldn't--unless I had a big budget for specimens, spectrascopes, etc."

S.F., 5-6-85:
"I enjoyed Dr.Carter's lectures--he keeps to the point and they're casual enough so there's a personalness, not just a big lecture where he's standing.--and the way he interacts is something I'll remember. Demos were helpful in lecture--active involvement is really important, helps me to remember for test."

"The part of the class I liked the best were the demos and the labs."

INT:"Are you any more confident in your ability to learn science?
S.F.:"Yes, I've just learned that it takes me alot longer than other people. so it's not impossible."

INTERVIEW QUOTES: Summer 1985

CHANGE IN ATTITUDE:

B.Del., 7-24-85:

INT: "On the pretest you indicated high anxiety towards science. Has it changed since taking this class?"
B.D.: "This class has decreased it tremendously. This is my first term in 10-12 years and I wanted to get this class out of the way quickly. INT: "Do you have more enjoyment of science?" B.D.: "I look at everything differently. Just the phenomena that we study. I try to understand everything now. It drives my family crazy."

INT: "What do you remember about past science courses?"
B.D.: "None in elementary school. Junior high was just basic science, mostly reading and problems. High school was real competitive academically. Did some labs, but mostly pencil."

INT: "Would your recommend this course to someone with high anxiety towards science.?" B.D.: "Yes." INT: "Why?"
B.D.: "You wouldn't have anxiety anymore. Class you enjoy going to and I had a high anxiety to start out with. The atmosphere of the classroom is very positive, pro-learning, very helpful, very non-threatening, felt you wouldn't be ridiculed."

K.D., 7/19/85:

INT: "On the pretest, you indicated high anxiety towards science and in your ability to learn and teach science. How has your anxiety changed since taking this class?
K.D.: My anxiety has decreased considerably. I can't say that I don't have any anxiety left. I still have anxiety about science and I really think that's because of the lack of science preparation I've had. However, I feel more confident now in my teaching aspect. I will approach science in a different respect."
K.D.: "I feel more comfortable about teaching. I really feel I've just scratched the surface and that worries me because I need to take more science courses to be an effective science teacher."
INT: Did you feel this class was a step in the right direction?"
K.D.: "Yes, definitely. It even changed my mind about math, if you can believe that. My anxiety about taking some of my math classes isn't as great because one of the things you said was of importance and I think it applies to math also and it really struck a chord with me--You said always break everything down to the basics and go from there. And if I keep that in mind I can handle it."

INT: "What helped change your attitude?"
K.D.: "First, the grading system--anxiety is out of the grade so I can relax and enjoy learning. I even find myself applying it in my everyday surroundings and I even pick up the paper and read the science section occasionally. Secondly, I liked the book and the conceptual emphasis and the de-emphasis on math. Third, the lectures were particularly helpful. And the Lab reinforced the lectures-- being able to talk about it."

INT: "Would you recommend this course to someone with high anxiety towards science?"
K.D.: "Yes. It should be a prerequisite. You have to understand these concepts--know what's going on in the world around you, even if your're not going to teach science."

P.L., 7-22-85:

"My elementary teachers had a very bad attitude towards science and it effected my attitude. . . Since taking this class, I enjoy science more, but my anxiety is still high. . . It's good to be anxious, keeps you on your toes. I will feel more comfortable if I take physics again."

L.S., 7-22-85:

"In elementary school, science and math were my worst subjects. My teachers taught it because it was their job, they didn't enjoy it. . . Probably all the anxiety came from the past experiences in other science classes--I didn't do good--didn't want to put alot of effort into them."

B.D., 7-23-85:

INT: "Has your anxiety decreased since taking this class?"
B.D.: "Yes, I still have some but I'm more comfortable to teach and learn. I don't have all the answers, but I feel I could challenge kids to start searching for answers."

INT: "What is the source of your anxiety towards science?"
B.D.: "Difficulties in classrooms and near failure experiences. . . In high school chemistry, if I didn't have a good partner, I never would have passed, didn't know what was happening. College chemistry was better, I could handle the memory and pass the tests. The labs were still beyond me. Int: "Why were they difficult?" B.D.: "I needed more time to figure them out. I didn't know what we were supposed to be doing when we were in there--pour this in here, pour that in here and watch it cook. Well, what is this? --the purpose?"

C.H.C., 7-23-85:

INT: "On the pretest, you indicated high anxiety towards science. Has your anxiety towards science changed since taking this class?"
C.H.C.: "Yes. I'm more comfortable with teaching it. I don't think it's so hard as I thought it was . Like using examples and demonstrations--kids can really enjoy it and I will be capable of handling it."

S.V.D., 7-23-85:

"My anxiety towards science was high before this class. I'm still rushed because of time, but it's been very interesting, really enjoyed it. It increased my enjoyment of science."

P.C., 7-23-85:

INT: "On your pretest you indicated fairly high anxiety toward science and physics. Has it changed since taking taking this class?"
P.C.: "It has decreased quite a bit. . . The pace of the class and the way the instructors teach it through guided discovery method results in alot less anxiety. I wish I had taken more science. I just took the minimum to get by."

INT: "What were you experiences like in past science classes?"
P.C.: "In 5th grade, it was discovery, not guided. In 6th grade, it was textbook and we fit it in when we had time. Only did 3-4 chapters. My attitude was apathetic. I didn't care about it. It was never stressed in my classroom so I didn't think it was important. In 7th grade, I had a good science teacher--physical science. In 8th grade, we didn't do much--life sciences. In 9th grade biology, the teacher had a bad attitude. Quite a few labs, but not tied to concepts very well--didn't learn much. I struggled with college biology because it was so in-depth. Nat. Science 115 was very good. I developed more appreciation for science."

S.B., 7-24-85:

INT: "Has your high anxiety towards science changed since taking this class?"
S.B.: "It has changed alot because I know alot now. The word science and physics scares you in the first place because I never had exposure to it before--afraid of unknown. In this class, the hands-on experience gets you into it, so it's part of your daily life and you have a base you can draw from."

INT: "Describe your past experiences in science."
S.B.: "I can't remember very much about elementary. In junior high, I had Bio Sci and earth science. High school biology was a good class, alot of labs. In College Bio Sci it was fill-in-blanks lab, no hands-on, charts on the wall, no specimens. Nat Sci was fill-in-blank, no experimentation. Science Methods was limited--I was disappointed. It gave me things to go, but I'd like to know more things to do."

INT: "Would you recommend this class to someone with high anxiety towards science?"
S.B.: "Yes, it's alot of work, but it's a good way to decrease your anxiety about science. It's things you need to know to teach. I realized now how little I knew before this class and it makes you want to learn more. It will help their anxiety."

CHANGE IN KNOWLEDGE:

B.Del., 7-24-85:

INT: "How has the lab helped you understand waves?"
B.D.: "I never thought about waves before except water waves. It's been an eye opener. Waves are everywhere."

"Compared to other parts of the course, the lab was the best--A+."

INT: "Do you see the relevance of learning waves to everyday life?"
B.D.: "Mainly light--I think about all aspects of it. Describing how black absorbs. It's what you're not seeing--that really struck me."

K.D., 7-9-85:

INT: "Do you think you would have really understood diffraction without doing the lab?"
K.D.: "No. I mean I would have known the definition of diffraction, but I really wouldn't have understood how the waves were diffracted as they came through the slits."

P.L., 7-22-85:

INT: "Do you ever relate waves to everyday life?"
P.L.: "Yes, the Doppler effect, when cars pass me; my stereo, how sound travels around corners; sunsets."

L.S. 7-22-85:

INT: "Can you relate waves to everyday experiences?"
L.S.: "I'm driving my family crazy with examples--blowing on beer bottles--this is resonance!!"

B.D., 7-23-85:

INT: "Can you relate waves to everyday experiences?"
B.D.: "Yes, singing in the shower--resonance; my son outside mowing the lawn, I know where he is."(inverse square)

INT: "Has the lab helped you understand waves?"
B.D.: "Yes, the buzzer, color slides. The slinky was neat-kids could get off on this on elementary level."

S.V.D., 7-23-85:

INT: "Did the lab help you learn about waves?"
S.V.D.: "Yes, the slinky was excellent. It was a very good explanation and it could be used for all different ages. Some kids have them at home so it's not foreign to them."

P.C., 7-23-85:

"I strongly recommend this class. We discussed so many things around you that you don't notice and you can't notice, e.g., why sunsets are red, why sky is blue. . . I would like to see this course a basic requirement of the university because we discuss so many things that go on around us everyday. It builds up your basic knowledge."

S.B., 7-24-85:

INT: "Has your appreciation of the dynamics of science changed?"
S.B.: "Lab taught alot of these skills and gives you much more awareness when you're observing things. You just can't take things for face value anymore. You want to know why--why the sky's blue--those kinds of things you always wonder about-- but I observed them in a different way before I took this class."

CHANGE IN LEARNING/TEACHING SKILLS:

B.Del., 7-24-85:

INT: "Has the way the lab was taught influenced the way you will teach?"
B.D.: "Yes, I would include alot of science. The atmosphere that's created in the classroom is just trememdous--like a team approach. I've been involved in sports and

it's the same kind of feeling, although the goal is a little bit different. You get to know people more on an interpersonal basis."

<u>INT</u>: "Do you see the relevance of learning about waves and teaching them to kids?"
<u>B.D.</u>: "Yes, for example sound waves are important. The ripple tank is the most graphic, see it. And then transfer it to sound."

<u>K.D., 7-19-85</u>:

"I took the whole world around me for granted--never even stopping to think how things happened. Now I find myself wondering how something happens, where before I never did."

<u>INT</u>: "What in the lab was conducive to learning?"
<u>K.D.</u>: "The informal part, someone to talk to--you or other classmates. If I didn't understand everybody always took the time to help me with it. Lab was a good reinforcer."

<u>P.L., 7-22-85</u>:

<u>INT</u>: "Would you recommend this class to other students?"
<u>P.L.</u>: "Yes, it's a fantastic class, very enriching, learn alot--not just reading passively. It influenced the way I'll teach."

<u>L.S., 7-22-85</u>:

<u>INT</u>: "As prospective elementary teacher, is there anything in lab that will influence the way you will teach?"
<u>L.S.</u>: "I like small groups--better, more attention, able to do it yourself."

<u>INT</u>: "Have you seen the relevance of waves in everyday life and the importance of teaching them?
<u>L.S.</u>: "Yes, I will use the slinky and the ripple tank."

<u>INT</u>: "Would you recommend this class to other students?"
<u>L.S.</u>: "Yes, because there's alot of practical applications and personal attention and I really learned alot. It's just not a class you take to pass and get credit for. This is different from other science classes I've taken."

"I wanted to do better because you cared. You know our names. I've never had a class where they knew my name."

<u>B.D., 7-23-85</u>:

<u>INT</u>: "Would you recommend this class to other students?"
<u>B.D.</u>: "Yes. It's something you can handle. It's not so in depth that you walk away from it without completing it. It's a real motivator, gives alot of ideas. If I had to

write a science unit for a methods class, I sure know where I've got some material."

L.E., 7-23-85:

"If this would have been a lecture class rather than a lab--would've gotten a worse grade. I have a good memory, but doing it is more helpful."

INT: "Would you recommend this class to other students?"
L.E.: "Yes. You learn through doing rather than osmosis. It seems it'll last alot longer."

INT: "Has this class influenced the way you'll teach?"
L.E.: "Yes, I really liked the hands-on. . . "I can see setting up these experiments in my classes--modifying them. It justs gets the point across more visually to me. . . Slinkies were really graphic--they (my students) could see and test."

"In Bio Sci 202, it was 99% memorization. The lab was more for the right answer rather than why. Whereas in this class we answer why. This class emphasized--ok, if I didn't get the right answer as long as you knew the theory and knew where experiment went off track. In 202, you just did wrong--never knew why it was wrong. In this class, there's substantiation to your errors."

C.H.C., 7-23-85:

INT: "Did the lab help you learn about waves?
C.H.C.: "Yes, definitely. . . Extremely helpful. . . Experiments helped me to do better than hearing lectures. They reinforced my desire to use experiments when I teach."

INT: "Do you feel the lab helped prepare you to teach?"
C.H.C.: "Yes, I have a file of experiments and will keep the book."

INT: "As a prospective elementary teacher, do you feel it's important to teach waves?"
C.H.C.: "I would want to teach them everything we learned. . . Sound and light are relevant to the world."

INT: "Would you recommend this class to to other students?"
C.H.C. : "Yes, it'll help them feel more confident about teaching it and it'll teach them certain methods that may be they won't get in their methods class. I've heard that they don't get anything out of it (methods class)--waste of time."

S.V.D., 7-23-85:

INT: "Did the lab influence the way you'll teach?"
S.V.D.: "Yes, the labs have helped me alot. They've cleared up alot from lecture. The step-by-step processes done in lab has really helped. . . Lab in comparison with other aspects of the course was extremely helpful."

INT: "Has the class helped you to teach children?"
S.V.D.: "I don't know how well I could teach. I would want to study them more, but at least I could explain the basics. Before I never would have tried alot of these things."

INT: "Do you see the relevance of teaching waves to children?"
S.V.D.: "Yes, I wish I'd known this when my children were younger and I could have incorporated it in their learning."

INT: "Would you recommend this class to other students particularly if they had high anxiety toward science?"
S.V.D.: "Yes, I made it through. It exposed alot of new ideas to me--some that I had some knowledge of, but couldn't really explain why. Now I have a little better idea especially in teaching kids and answering their every-day questions."

P.C., 7-23-85:

"I took science methods last term. It was very useful, did micro-teaching assignments and went into the schools. I learned how little I knew in science and how much I had to learn in science to be a competent teacher. We wrote our own lesson plans--I didn't know what I was supposed to teach. Would have been better to have had PHS 203 first. In this course we got content and how to do the teaching especially through the labs."

INT: "How has the way the lab was conducted influenced the way you learned and how you will teach?
P.C.: "Unfortunately I had the idea of having a classroom where I'd be doing the lecture, very structured, very didactic. I'd be lecturing and my students would be listening. I've got to change my mind about this and this course has helped because I've understood through my own lab experience--by working with other students and hearing my own peers speaking about it. In my own class, I'll encourage my students to talk among themselves. So it was a good experience with this approach. It has changed my mind about how to teach."

INT: "Do you see the relevance of teaching waves to your students?"
P.C.: "Big relevance. It's a part of everyday life. In order to understand what's going on around you and to make it seem less magical--they must understand waves."

S.B., 7-24-85:

INT: "Has the lab influenced the way you'll teach?"
S.B.: "Yes, you learn alot more with hands-on experience especially with this kind of stuff. I would go to lecture and listen and read the book and I'm not a very good book learner. There's alot of different ways to learn and alot of kids and people learn with hands-on experience, actually doing it and seeing it. You remember those kind of images alot longer than you do from reading from the book or somebody lecturing to you. I want to do alot of that when I teach--kids really get into it and they learn alot."

INT: "So, this class matched different learning styles with the text, lecture and lab covering several things?"
S.B.: "This helps me alot. Just getting it from a book. If you've never been exposed to it before, you don't know what to draw or how to draw it out of book. So lecture pulled out what you needed to know and lab let you sit down to tinker with it to see how it worked."

INT: "Do you see the relevance of teaching waves to elementary kids?"
S.B.: "Yes, I see alot of relevance, just how waves work on the water. Kids are familiar with it, but don't know what goes on. Electricity, light waves, rainbows, everything around us."

APPENDIX C: ETHNOGRAPHIC DATA

The following collection of student quotes are referred to in this research as "Ethnographic Data". Included in the "Ethnographic Data" appendicies are student quotes from "The Special Research Exercise", "Interviews", "Transfer of Learning/ Teaching Skills", and "Anonymous Quotes". Quotes are divided into separate sections for Spring term and Summer term. Appendix C refers only to Transfer of Learning/Teaching Skills. The Transfer of Learning/ Teaching Skills research instrument is on the next page.

CATEGORIES FOR TRANSFER OF LEARNING/TEACHING SKILLS QUOTES

GOOD ROLE MODEL: HIGH TEACHER CONCERN FOR STUDENTS
Student quotes: Spring term, p. 222; Summer term, p. 226

GOOD ROLE MODEL; TEACHING TECHNIQUES AND RESOURCES
Student quotes: Spring term, p. 222; Summer term, p. 226

SCIENTIFIC PROCESSES; ACTIVITY-ORIENTED SKILLS
Student quotes: Spring term, p. 223; Summer term, p . 227

EASIER LEARNING: CONCRETE EXPERIENCES
Student quotes: Spring term, p. 224; Summer term, p. 228

SMALL GROUP ENVIRONMENT: MORE INDIVIDUAL INVOLVEMENT
Student quotes: Spring term, p. 224; Summer term, p. 228

LESS ANXIETY, MORE ENJOYMENT & CONFIDENCE IN TEACHING
Student quotes: Spring term, p. 224; Summer term, p. 230

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This is a copy of the open-ended laboratory questionnaire given to the students during the last week of the class each term. Quotes taken from Question # 3 of this exercise are listed under the "Transfer of Learning/Teaching Skills" section in the Appendix C.

RESEARCH EXERCISE: PLEASE PUT YOUR NAME, DATE AND SECTION ON AN 8 x 11 PIECE OF PAPER AND ANSWER THE FOLLOWING:

1. HOW WELL CAN YOU SUMMARIZE & COMPARE SOUND, LIGHT, HEAT AND ELECTRICITY AS WAVES? YOU MAY TRY TO USE A GRID LISTING THE 4 TYPES OF WAVES ALONG THE TOP AND LISTING THE NAMES OF WAVE PROPERTIES ALONG THE SIDE. THESE PROPERTIES MAY INCLUDE SOURCE OF WAVE, WAVELENGTH, WAVE TYPE, DOES IT DIFFRACT? REFRACT? REFLECT? ETC. ANSWER THE QUESTIONS WHERE THE COLUMNS & ROWS CROSS ON THE GRID IF YOU ARE USING ONE. SEE EXAMPLE BELOW.

2. WHAT IS THE MOST SURPRISING IDEA YOU HAVE LEARNED ABOUT WAVES? WHAT STILL SEEMS TO BE CONFUSING ABOUT WAVES? PLEASE EXPLAIN.

3. HOW HAS THE HANDS-ON, SMALL-GROUP LABORATORY EXPERIENCE INFLUENCED YOUR ATTITUDE AND SKILLS TOWARD LEARNING SCIENCE AND TOWARDS YOUR PROSPECTIVE TEACHING OF SCIENCE? PLEASE SPEND SOME TIME ON THIS ONE.

THANK YOU FOR YOUR THOUGHTFULNESS AND SINCERITY.

PLEASE RETURN AS SOON AS POSSIBLE.

QUOTES: TRANSFER OF LEARNING/TEACHING SKILLS
SPRING 1985

GOOD ROLE MODEL: HIGH TEACHER CONCERN FOR STUDENTS

M.C., 6-6-85: "This course has definitely changed my attitude and I must thank my instructor(s) once again for making it such a rewarding experience--for helping me to learn something that I didn't think I could do so well at, at the beginning of the term! It's nice to know I can now be a more confident teacher in the science field."
M.L. 6-6-85: "..., you have been a great help in understanding this class. You are a fine example and I hope that I can do as fine a job as you have of teaching. You guys go out of your way to help us understand and we have fun while we learn."

GOOD ROLE MODEL: TEACHING TECHNIQUES AND RESOURCES

B.D., 6-6-85: "Lab was an essential part of this class and it greatly helped me learn the topics taught. The labs also gave me a generous amount of ideas to use for my teaching experiences. There wasn't very much that would have to be changed to incorporate most of those labs to a class of younger students."
M.A., 6-6-85: "I learned . . . how to conduct a lab, how to use resource materials. I have 9 labs I can use if I can get the materials . . . . I really enjoyed lab and feel that I learned alot from it and that I could go out and teach using a lab to help my students gain understanding of the scientific topics successfully."
M.C., 6-6-85: "I think the most important thing a student can do to learn is by 'doing'--that's what we did in this science class. I will do the same with my students--I will make them 'do', become scientists themselves--to teach them to think for themselves and solve problems after they have observed and predicted."
J.C., 6-6-85: "The hands-on labs have been helpful in giving me some idea of what kinds of labs I could do in my classroom. I have enjoyed most of the units in this class."
M.L., 6-6-85: "Science isn't going to be any fun unless the children in my classroom are effected by it. If they can't participate and see for themselves that what they are learning is actually true, what good is it? Science is for them too! They can be scientists and that it is nothing to be afraid of. If I can learn this way, they certainly can. And if it helped me and I enjoyed it, so can they enjoy it and gain understanding."
J.B., 6-6-85: "Ultimately, I feel this type of experience (lab) is imperative at a young age for comprehension of abstract scientific concepts to occur. When I teach science, I will base my units around how I can demonstrate and let the child manipulate what is being taught."

S.M., 6-6-85: "Working in small groups was constructive to my learning and I hope to use or have the opportunity to work with small groups when I am teaching science. I also think our lab instructors modelled effective techniques for developing the problem-solving techniques in students."
L.B., 6-6-85: "I now think that I would enjoy letting kids learn thru this lab or hands-on experience, as my own feeling towards physics has improved greatly!"
A.L. 6-6-85: "I have learned that using small groups and giving a good explanation of the material helps the students in the lab. When I teach science lessons I plan on utilizing the strategies that I learned in lab."
L.C., 6-6-85: "The hands-on, small group lab experiences have completely changed my attitude about how I can teach physical science and science in general. Prior to the class I wasn't exactly confident in my own ability to teach science. My classes in high school and college dealing with science for the most part were just reading and taking tests continuously. To be a good teacher you must be able to apply and teach what you know. You have to do more than just be able to define words. This is really the first class that taught me how to apply what I learned in a classroom. I'm looking forward to using many of the activities/ hands-on projects in my classroom nest year. Good work Guys!!"
C.H., 6-6-85: "The hands-on small group lab experience has given me ideas to use in my classroom. It has exposed me to different equipment, techniques and methods that can be used to give students experiences that will help them remember and understand material. It has given me ideas as to what may or may not work with a group of younger students because I have seen it from my perspective as the 'lab worker'."

SCIENTIFIC PROCESSES: ACTIVITY-ORIENTED SKILLS

M.C., 6-6-85: "The laboratory experience allowed me to become a scientist--I had to observe, predict and apply my knowledge."
M.L., 6-6-85: "The hands-on, small group laboratory is a must. You remember what you did longer because you yourself proved a theory! What lecture didn't cover, or help me understand, the lab did."
M.S., 6-6-85: "Many times I didn't understand the concepts being given, until I actually created it myself."
L.B.,6-6-85: "I've realized how much easier and quickly ideas and concepts are grasped when you can manipulate the factors yourself and as many times as you need to to see them."

EASIER LEARNING: CONCRETE EXPERIENCES

F.R., 6-6-85: "My hands-on experiences in the small groups has given me more reason to believe that students learn better with first-hand experiences. When you are able to work out a problem by actually working with it first-hand you receive more and you are more likely to remember it. Just hearing how an object works as in lecture isn't as fulfilling as figuring out how it works on your own."
M.A., 6-6-85: "Without lab, I would not have learned very much at all."
J.B., 6-6-85: "I feel that lab and the hands-on saved me from flunking."
M.S., 6-6-85: "(Lab experiences) are reference points for me, now when I try to think of the definition of a term."
L.B., 6-6-85: "I've realized how much easier and quickly ideas and concepts are grasped when you can manipulate the factors yourself and as many times as you need to to see them."
A.L., 6-6-85: "Without hands-on experience one really does-not know if they know the information. It also helped to talk about what you were doing in lab. By using this approach Tom could tell you what you didn't know."
M.E., 6-6-85: "These labs have shown me, and taught me that science isn't really as difficult as it seems at first. By doing these experiments and lab problems, it helps me greatly, because by doing these things I learn what i"m doing right and/or wrong, I can go back and do the experiments again and see where I went wrong and then I can correct it and learn it right."

SMALL GROUP ENVIRONMENT: MORE INDIVIDUAL INVOLVEMENT

C.S., 6-6-85: "The small group lab has shown me that learning by doing with other people can be fun. It has improved my attitude about learning science because it has shown me I can learn."
A.L., 6-6-85: "It also helped to work in a small group. If one works in a large group they don't get the hands-on experience."
M.L., 6-6-85: "The hands-on, small group laboratory is a must. You remember what you did longer because you yourself proved a theory! What lecture didn't cover, or help me understand, the lab did."

LESS ANXIETY, MORE ENJOYMENT & CONFIDENCE IN TEACHING

M.C., 6-6-85: "I've said it over and over again: lab has influenced my attitude in a very positive way from one that was very negative. I felt this class was extremely difficult because I started out knowing zero about physics, now I know a great deal more. ... Now I can go forward teaching science if I get the opportunity with a great deal more confidence. I hope I get the opportunity to teach some of the labs I did--in my own classroom."

J.C., 6-6-85: "This class has changed my attitude toward teaching science to children. I feel competent that I could do almost a entire year of science lessons just from the material I learned in this class."
M.L., 6-6-85: "And if it (lab) helped me and I enjoyed it, so can they (my students) enjoy it and gain understanding. I can teach this stuff because I can understand it and demonstrate it and help the children to demonstrate it, too."
M.S., 6-6-85: "The hands-on, small group lab experience has given me a more positive attitude towards science and the teaching of it."
S.M.,6-6-85: "My lab experiences have developed my positive attitude further towards my learning and prospective teaching of science."
A.L., 6-6-85: "My attitude toward science is much better now than it was 10 weeks ago. You made science fun again."
L.C., 6-6-85: "The hands-on, small group lab experiences have completely changed my attitude about how I can teach physical science and science in general. Prior to the class, I wasn't exactly confident in my own ability to teach science. My classes in high school and college dealing with science for the most part were just reading and taking tests continuously. To be a good teacher, you must be able to apply and teach what you know. You have to do more than just be able to define words. This is really the first class that taught me how to apply what I learned in a classroom."
C.H., 6-6-85: "I have a more positive and confident attitude about teaching science and a lot of it can be attributed to the lab experience. Because my attitude towards science has improved, I think I have a better ideas of the kinds of things that might motivate students and encourage them to experiment and learn."

QUOTES: TRANSFER OF LEARNING/TEACHING SKILLS
SUMMER 1985

GOOD ROLE MODEL: HIGH TEACHER CONCERN FOR STUDENTS

B.W., 7-22-85: "I never used to like science because many of the courses that I had you were given the material and told to do what it said to and ask questions if needed. But nobody did because we were given the impression that we would be bothering the teacher. In this class I was given the impression that the teachers really did care and this was more helpful than even the hands-on work."

GOOD ROLE MODEL: TEACHING TECHNIQUES & RESOURCES

J.P.,7-22-85: "I now feel much more comfortable in a lab situation and plan to involve my students in such a situation. Lab allows the student to experience science in a low-anxiety environment, if it is set up properly."

K.D., 7-22-85: "Children definitely like 'hands-on' methods and through this lab and lecture I have been able to compile a list of experiences that correlate with different concepts to use with children. It also aids their memory and helps them to learn by application not only memory alone."

S.G., 7-22-85: "Science is so fascinating and so unbelievable. Hands-on experiences are a way of actually observing and taking part in science phenomena. Children are curious and want to know how, why, what if. By all means, they should be encouraged to ask questions, seek answers, be creative, wonder, discover. This wondering is what helps children grow and mature in knowledge and understanding. In order for children to discover, they have to experiment. They have to participate. This means they need hands-on experiences."

S.G., 7-22-85: "It is due to the positive influence of my small, hands-on labs that I am a believer in teaching science the same way in my classroom. During the labs, I have participated, discussed, observed, predicted. I met and worked with alot of people--friends--and I learned to advise them, aid them, and seek their assistance and advice. We learned how to be a team and be productive."

S.G., 7-22-85: "If I can make my science lessons as awakening, comfortable, and manipulate, I'll be a good Science teacher."

P.C.,7-22-85: "By working with the people in my lab (small group) I believe I have a better understanding of physical science now than when I began this course. . . .There is only so much help and attention an instructor can divide among students, so it's to the students' advantage to have others around when the instructor is busy with others."

C.B., 7-22-85: "When I teach hands-on will be an important part of my curriculum. In order to change students misconceptions, they must be able to observe and manipulate phenomena."

P.P., 7-22-85: "It (lab) has helped me to see the concepts being discussed first-hand, and the labs have given me some good ideas and experiments to use when I get into a classroom. . . It would be difficult to do most of these labs in small groups with (very small) children, but on a large scale they could help and participate, see and ask questions and discuss what was happening and try to discover why."
S.V., 7-22-85: "The labs we have done are good examples for our future classrooms, both in how learning by hands-on and in how to set up experiments. Also how important it is to understand the different learning abilities and rates of various students. Each student in a classroom should be involved as much as possible in experiments."
B.DEL., 7-22-85: "Beyond the concepts which I have learned, I value the teaching techniques employed--especially in lab. I hope I can make the learning of other subjects as enjoyable to my students as PHS 203 has been for me."
J.M., 7-22-85: "Before this class the only science I imagined teaching in those early grades (K, 1 and 2) was nature--hikes, plant seeds and watching them grow--and nutrition. Now I have a whole new idea of elementary school science."
L.S., 7-22-85: "When I'm in the classroom, I also plan to do something of this type. I think I will be able to help more children in a closer more personal manner. I also think it will help with keeping their attention longer having to do the experiments on their own. . . . I plan to try to spend much of my class time interacting and helping the students with their separate problems they're having on a specific area. I really liked the lab write-ups too. I thought they aided in the reinforcement of the previous chapter. I realize a lab write-up in the 4th or 5th grade could be on the confusing side, but I also feel that we do not challenge our children at an early enough age. I believe they could accomplish a simple write-up and do it well."

SCIENTIFIC PROCESSES: ACTIVITY-ORIENTED SKILLS

B.D., 7-22-85: "As a teacher, I don't expect to know all the answers. I only expect to challenge the student to want to find out and then demonstrate ways they can continue their search."
S.G., 7-22-85: "I'm sold on the hands-on laboratory experiences. I don't see how a lab could be any other way. I need to observe and manipulate materials. I need to cause interaction between things and observe the outcome."
C.B. 7-22-85: "It (lab) has developed a positive attitude toward science because I can manipulate and control the subjects talked about in lecture."
S.B., 7-22-85: "The lab experience also pushes for hypothesizing, thinking things through and stretching my mind to figure things out. It makes science fun and clears

up alot of questions that otherwise I would not have been able to see."
S.B., 7-22-85: "Somehow actually doing, creating and looking at it leaves a firmer image in my mind and makes it easier for me to apply to other situations--having worked with, and seen it rather than having to apply it straight from the book."

EASIER LEARNING: CONCRETE EXPERIENCES

B.W., 7-22-85: "The hands-on work was good because it tied in what happened in lecture and in the book. I personally think it was the most important part of the course because it gave the opportunity to do what was being talked about."
K.D., 7-22-85: "Lab experience has helped me to relate the different types of energies and some of their properties. Lab has helped me clarify some of my ideas, thoughts and helped clear up confusion by being able to talk it through with peers and instructors. Through lab experience I have been able to reflect and that reflection has helped me answer questions that came up."
S.G., 7-22-85: "I may have still been a little confused after observing the wave pattern in the ripple tank, but I knew more than if I had only read about the pattern or been told about it. Seeing is believing and I think this is especially true for science and for children."
M.M., 7-22-85: "Actually working with the materials we are discussing in lecture somehow makes the concepts more concrete and meaningful."
P.P., 7-22-85: "I have gained a better understanding of the nature and properties of science that I didn't have or was confused about before."
S.B., 7-22-85: "The hands- on, small group lab experience has definitely had a very positive effect on me. It was the place where I could come with all of my confusing lecture notes, or ideas from the book or look at some new and interesting aspects of the topic and actually try them out and see if what everybody says about it is really true."

SMALL GROUP ENVIRONMENT: MORE INDIVIDUAL INVOLVEMENT

B.D., 7-22-85: "The best advantage (of lab) is when there is time to compare with other students and chat a bit."
S.G., 7-22-85: "During the labs, I have participated, discusses, observed, predicted. I met and worked with alot of people--friends--and I learned to advise them, aid them, and seek their assistance and advice. We learned how to be a team and be productive."
P.C., 7-22-85: "The small groups have shown me how important discussion among peers in a guided-discovery classroom situation is. It is so much easier, and so much more educational for students to discuss their findings with others. . . . By working with the people in my lab, I

believe I have a better understanding of physical science now than when I began this course."

C.B., 7-22-85: "The small group helped in that they had the same comprehension problems that I did and we could all work together to help each other understand. . . Each student can have a specific role during lab and not just sit and let others do all the work. Works great for low achievers!

M.M. 7-22-85: "Before I always considered myself too dumb to ever understand anything scientific. This class is helping me to see that this is definitely not the case. I think alot of it has to do with the small group lab experiences."

L.E., 7-22-85: "I have always liked to work in groups so you can discuss your answers and express your logic. It helps to defend your understanding thus many misconceptions can be caught in the early stages and not get work into final understanding of the concept. I think children also need to have their predictions tested promptly so they get immediate feedback, thus small groups accomplish this."

S.V., 7-22-85: "The small lab groups are a very definite advantage to learning and has increased my understanding of readings and lectures in this class."

C.C., 7-22-85: "As for my own learning, this hands-on and small group lab experience has been great. . . It lets each person become involved and able to see/do experiments and get results for themselves."

S.B., 7-22-85: "The small group atmosphere I think is really great. There is absolutely nothing worse than sitting alone with some foreign material that you can't figure out or that you can't seem to see clearly through to the answer. A small group atmosphere offers support, new alternatives and view points to the situation, explanations when you've forgotten or don't understand, some one for me to talk things through with. It just lightens the load a bit. . . It is a really good feeling to have worked together to figure something out, talk all of us through it until we understand the material more clearly and we have mastered the topic successfully. I really enjoy that lab time."

L.S., 7-22-85: "I thought the small groups were a very good instructional tool. They allowed individuals to gain the attention that they may need and also lets the students work on the experiments themselves. They get the practical hands-on experience that is needed for a better understanding of the concept."

S.S., 7-22-85: "I feel that the lab groups have helped me out personally very much. Because in the small group you have an opportunity to develop friendships you get to feel comfortable with those you are working with. You don't feel stupid asking the other group members a question or two about something you don't understand. You don't have a change to ponder about any anxieties you may have about science (physics in particular), because you are a team mem-ber. I feel that this--small group--was one of the keys of my success in the class."

LESS ANXIETY, MORE ENJOYMENT & CONFIDENCE IN TEACHING

J.P., 7-22-85: "I want to stress that I feel much more competent in the science area and I am much more willing (even a little excited) to teach science."
B.D., 7-22-85: "I have gained insight through this class into the value and importance of teaching physical science. I still find the study of the human body more fascinating and before this class, would have avoided physical science altogether. I feel now that I could prepare lessons to teach this area, that it would be beneficial to those students in particular, in my classroom, who were not interested in the human body."
S.G., 7-22-85: "I was very intimidated and anxious about taking this course. I later became quite comfortable with the concepts and the labs. If I can make my science lessons as awakening, comfortable, and manipulative, I'll be a good Science teacher."
M.M., 7-22-85: "So I think that by actually experimenting with some of the materials that demonstrate scientific concepts, I have gained confidence in myself and learning science which I know in turn will improve my teaching."
B.DEL.,7-22-85: "This is my first term back in school in about 13 years. I took physical science because I was concerned about it and wanted to get it over with quickly. My goal is to become an elementary teacher. To date, I have not declared my minors and had not even considered science as a possibility. I have enjoyed the hands-on and small group experiences so thoroughly that I am considering science as one of those minors. If I do not choose it as a minor, I know I will incorporate it strongly when I get my own classroom."
J.M., 7-22-85: "The most important thing I feel lab has done for me is to help me realize that science can be fun. It's more than theories, equations and boring lectures. Science can be connected with many other subjects, and specific concepts such as waves can easily be taught in K, 1, and 2."

APPENDIX D: ETHNOGRAPHIC DATA

The following collection of student quotes are referred to in this research as "Ethnographic Data". Included in the "Ethno-graphic Data" appendicies are student quotes from "The Special Research Exercise", "Interviews", "Transfer of Learning/ Teaching Skills", and "Anonymous Quotes". Quotes are divided into separate sections for Spring term and Summer term. Appendix D refers only to the Anonymous Quotes.

The research instrument for the anonymous student quotes was the Michigan State University "SIRS form". The front side of this form has a statistical evaluation survey of the course. The back side of this form has a blank page where the students can write any additional impressions about the course. The students were given class time to complete this blank page. They were encouraged to include any comments that they wished to make about this course. Not all students took the time to write comments.

CATEGORIES FOR ANONYMOUS QUOTES

GOOD ROLE MODEL: HIGH TEACHER CONCERN FOR STUDENTS
Student quotes: Spring and Summer terms, p. 232

GOOD ROLE MODEL; TEACHING TECHNIQUES AND RESOURCES
Student quotes: Spring and Summer terms, p. 232

SCIENTIFIC PROCESSES; ACTIVITY-ORIENTED SKILLS
Student quotes: Spring and Summer terms, p. 233

EASIER LEARNING: CONCRETE LAB EXPERIENCES
Student quotes: Spring and Summer terms, p. 233

SMALL GROUP LAB ENVIRONMENT: MORE INDIVIDUAL INVOLVEMENT
Student quotes: Spring and Summer terms, p. 233

LESS ANXIETY, MORE ENJOYMENT AND CONFIDENCE IN TEACHING
Student quotes: Spring and Summer terms, p. 234

PHS 203: COMPARISON WITH OTHER CLASSES: SCIENCE, METHODS, ETC.
Student quotes: Spring and Summer terms, p. 234

CLASS DESIGN: LABS, LECTURES, ETC., COMPLEMENTARY AND REINFORCING
Student quotes: Spring and Summer terms, p. 235

SUGGESTIONS FOR IMPROVEMENT
Student quotes: Spring and Summer terms, p. 235

ANONYMOUS QUOTES: SIRS FORMS: LAST DAY OF COURSE
SPRING 1985 & SUMMER 1985. Summer is marked with *.

Some quotes belong in more than one category, but are in the category with the major intent.

GOOD ROLE MODEL: HIGH TEACHER CONCERN FOR STUDENTS

1) "I felt very comfortable asking questions and staying after class for extra help."
2) "You're a great lab instructor. Your friendliness and general caring about student learning was very evident. . . I felt you were very helpful in making sure we learned the material."
3) "I was very impressed and happy to see the instructors genuine concern that the students understand the course--always was available for extra help when students needed it."
4) "The lab instructors were very concerned that we understood all of the material. There was alot of work to do, but it all helped me to understand the material whether I wanted to or not."
5) ". . . is a very enthusiastic teacher. He tries hard to help you understand the mateial. I appreciate your being available whenever we needed you."
*6) "I enjoyed your open, friendly personality, . . . You seem to really care whether or not we learn!"
7) "I am very grateful to . . . for his patience and understanding in helping me learn this material."
8) "I felt that the lab instructor was helpful in presenting material that was applicable towards test material. I appreciated extra time spent on question."
9) "I am thankful that I had . . . for a lab instruactor. I felt he really cared whether or not we 'learned' the material, not that we just wanted to get through the course."
10) "I enjoyed the lab class. It was interesting and educational. I also enjoyed the instructor. He looked as though he enjoyed what he was doing and conveyed a very positive attitude toward his students, helping us when we needed it. I'd recommend his class to others."

GOOD ROLE MODEL: TEACHING TECHNIQUES AND RESOURCES

1) "I think they did a super job! They are fine examples of teachers themselves. They make it interesting and you can tell they really care. I hope I can do as good a job as they! . . I gained alot of good ideas for my elementary classroom."
2) "Overall you're a good lab instructor and the way you present the material is also good."
3) "The demonstrations that were used were excellent and well-thought out."

*4) "I really enjoyed this course! Teaching approach excellent--concepts learned, much appreciated. Thanks."
5) "I enjoyed your enthusiasm and it seemed to transmit to the class. You are a great teacher--you have choosen your field well."
6) "It was nice to have a class where the instructor tests you on what you learned. . . Lab instructors were very thorough."
7) "I feel this is one course which will benefit me in my student teaching overseas and in my future teaching in the elementary classroom."

SCIENTIFIC PROCESSES: ACTIVITY-ORIENTED SKILLS

*1) "The labs were enjoyable because of the first-hand observations we could make."
2) "The hands-on experience was invaluable. The direct approach helped greatly."
3) "This is one of the (few) classes I have taken at M.S.U. where I feel I have learned a great deal. I believe alot of it had to do with the lab. I was able to have a hands-on experience with what I was reading and learning in lecture."
4) "I liked the chance to be able to do the experiments in lab to enhance my understanding of each topic we covered. You did a very good job! Thank you!"

EASIER LEARNING: CONCRETE LAB EXPERIENCES

1) "The class was very enjoyable and I found it an easier way to learn."
2) "I thought that this lab was very well organized and ran rather smoothly. The rate of instruction was helpful, because one didn't feel rushed and could better conceive the concepts."
3) "I was able to have a hands-on experience with what I was reading and learning in lecture. It made a great deal of difference in my understanding of the material."
4) "I really enjoyed the labs and they were very helpful in explaining and giving practical examples of the material that was presented in lecture."

SMALL GROUP LAB ENVIRONMENT: MORE INDIVIDUAL INVOLVEMENT

*1) "The way lab was taught was a good method, as the small-groups enabled us to get involved and learn for ourselves."
*2) "The lab experience has been helpful. I've enjoyed the small group discussions, and the way the class was presented. Low anxiety in this lab, if any at all."

LESS ANXIETY, MORE ENJOYMENT AND CONFIDENCE IN TEACHING

1) "He conducted class with a warm and friendly atmosphere making students feel very comfortable--my high anxiety went from high to low because I was always assured with a positive attitude and that 'I could do it'. . . This science class was a very rewarding and enjoyable experience for me and the instructors made this possible."
2) "I actually liked the class. I am surprised. Thank you. I will feel more confident in teaching science. Now I want to take more science classes."
3) "I liked the friendliness of the lab instructors and the friends I was able to make in lab."
*4) "Excellent class-I feel I really got alot out of the class both personally and professionally."

PHS 203: COMPARISON WITH OTHER CLASSES: SCIENCE, METHODS, ETC.

1) "Super class! One that I enjoyed more than any other science class I've had. I began this class dreading taking it. It was so much more enjoyable and I learned a tremendous amount of information about Physical Science and feel much more competent in teaching science."
2) "The lab was very helpful to me. I have never enjoyed any science class before. The science class was set up in a way in which students could understand the material. I actually liked the class."
3) "It is obvious that the instructors put alot of time and effort into perfecting this course. Organization and lab assignments were excellent."
4) "I liked the choice of topics that was covered in class. I liked the format, lab book, etc."
*5) "This is the best science class that I have had in terms of classroom applications. My methods science was a waste of time. Thanks."
6) "The set up of this lab and recitation was extremely helpful in improving my knowledge and abilities in the concepts talked about in lecture."
7) "I had . . . as an instructor and thought he was exceptional. This has been my favorite class at M.S.U. and I feel as though I've learned alot!"
8) "This is one of the (few) classes I have taken at M.S.U. where I feel I have learned a great deal. I feel this is one course which will benefit me in my student teaching . . and in my future teaching."
9) ". . . was one of the best lab instructors I've had. He went out of his way to be helpful to students. . . He couldn't have been better."
10) "This was a very good class and very interesting because I learned so many new things--that I always 'thought' I knew."

CLASS DESIGN: LABS, LECTURES, ETC., COMPLEMENTARY AND REINFORCING

1) "I think they did a super job! . . . The way everything com-plemented each other--lab, textbook, lecture, etc. was terrific. I gained alot of good ideas for my elementary classroom."
2) "I liked the way this class was set up."
*3) "Thank you for having such a good lab follow-up to the lectures. They certainly did clear-up alot of confusing facts. The experiments and handouts were a great help."
*4) "This has been a good experience. Labs reinforced concepts well. I really enjoyed the whole class."
*5) "I thought that the course was very informative and actually fun. I enjoyed the work. The fact that the course had 2 instructors was a great help in them being able to divide their time and spend more time with the individuals."
6) "I thank the lab was very cohesive with lecture and helpful for understanding the practical uses for each of the topics."
7) "I felt the combination of lectures, labs, and recit-ation were very thorough. It was nice to have a class where the instructor tests you on what you learned, rather than by using tricky questions, that only a few people could answer."
8) "Your reviews before the tests were very helpful. I really appreciated those! You seemed to be able to really focus us into the important information. Thanks."

SUGGESTIONS FOR IMPROVEMENT

1) "The only complaint is that some labs went very fast for me-not giving me time to absorb the concepts as I did them. However, I understand this was unavoidable in order to cover all necessary material."
2) "I feel you should try to circulate around the room more during lab. You seemed to stick mostly to one group in helping them and in asking them questions. This bothered me a bit. Otherwise, everything was okay."
3) "A film during lecture would be a welcome change to lectures."
*4) "At times, I feel that we were rushed--very rushed. . . Consequently, I don't think that lab was as valuable as it could have been. Obviously, with our 5 week time limit, some of the rushing could not have been avoided--I do understand that!"
*5) "I felt I would have got more out of this lab if you would have allowed more time for discovery."

APPENDIX E: RESEARCH INSTRUMENTS

Appendix E contains the research instruments involved with surveys, data tables, ethnographic data, and the course's laboratory exercise involving certain wave phenomena.

RESEARCH INSTRUMENT LIST

Background & Attitude Questionnaire Page 237
(Tables 1, 3 and 9)

Moore & Sutman "Scientific Attitude Inventory" Page 240
Coding corresponds to Table 2 subscales.

Open-ended Wave Questions (Table 4) Page 242

Wave Definitions (Table 5) Page 243

Wave Sketches & Explanations Page 244
(Tables G, 7 and 8)

Special Research Exercise Page 245
(Appendix A)

Transfer of Learning/Teaching Skills Page 246
(Appendix C)

Lab 2-Properties of Waves, Measuring of Sound Page 247

PHS 203 BACKGROUND & ATTITUDE QUESTIONNAIRE

THE INFORMATION WHICH YOU ARE ASKED TO GIVE IN THIS QUESTIONNAIRE IS FOR THE PURPOSE OF DETERMINING FACTORS WHICH ARE IMPORTANT IN LEARNING (OR TEACHING) SCIENCE, AND TO EVALUATE THE COURSE SO THAT IMPROVEMENTS CAN BE MADE FOR THE FUTURE. YOUR RESPONSES ARE TO BE USED FOR RESEARCH & EVALUATION ONLY, AND THEY WILL HAVE NO NEGATIVE AFFECT ON YOUR GRADE IN THIS COURSE. PLEASE TRY TO MAKE YOUR RESPONSES AS ACCURATE AS POSSIBLE.

DIRECTIONS: YOU SHOULD HAVE RECEIVED AN ANSWER SHEET & A # 2 PENCIL. PUT YOUR RESPONSES ON THE ANSWER SHEET ALONG WITH THE FOLLOWING INFORMATION ENTERED IN THE "BOXED-IN" REGION.

1. NAME 2. STUDENT NUMBER 3. SECTION NUMBER 4. COURSE NUMBER: 203 5. SEX: F or M
6. TERM: FA, WI, SP, SU 7. FORM: 1A

CHECK TO SEE THAT YOU HAVE DARKENED THE CORRECT BOXES BELOW EACH ENTRY.

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1. MAJOR: A. Elementary Education B. Social Science C. Child Development D. Special Education E. Other (please specify on back of answer sheet)

2. CURRENT YEAR OF STUDY: A. Freshman B. Sophomore C. Junior D. Senior E. Graduate or special student

3. TAKEN A COURSE IN HIGH SCHOOL PHYSICS? A. Yes B. No

4. IF YES, THE GRADE THAT I RECEIVED WAS: A. A B. B C. C D. D E. F

5. TAKEN A COURSE IN HIGH SCHOOL CHEMISTRY? A. Yes B. No

6. IF YES, THE GRADE THAT I RECEIVED WAS: A. A B. B C. C D. D E. F

7. TAKEN A COURSE IN HIGH SCHOOL BIOLOGY? A. Yes B. No

8. IF YES, THE GRADE THAT I RECEIVED WAS: A. A B. B C. C D. D E. F

9. TAKEN A COLLEGE COURSE IN BIOLOGICAL SCIENCE? A. No B. Yes, B.S. 202 C. Yes, a Natural Science course D. Yes, other

10. IF YES, THE GRADE THAT I RECEIVED WAS: A. A B. B C. C D. D E. F

11. IF YES, MY ATTITUDE TOWARD THE COLLEGE BIOLOGICAL SCIENCE COURSE WAS:
    Did not like it 1. 2. 3. 4. 5. Liked it very much

12. I HAVE TAKEN OR PLAN TO TAKE A COLLEGE COURSE DEALING WITH GEOLOGY, EARTH SCIENCE, OR ASTRONOMY: A. Yes B. No

13. I HAVE TAKEN A COLLEGE COURSE DEALING WITH PHYSICS OR CHEMISTRY: A. Yes, physics B. Yes, chemistry C. Yes, both physics and chemistry D. Natural Science course E. No physics or chemistry

14. WAS THE SCIENCE WHICH WAS TAUGHT TO YOU IN ELEMENTARY SCHOOL PREDOMINATELY STUDENT ACTIVITY ORIENTED? A. Yes B. No C. Science was essentially absent in my elementary school experience

Data from this survey has been compiled on different tables. Background data is in Table 1. Attitude data is in Table 3. Skills data is in Table 9.

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15. I AM TAKING THIS COURSE:

A. Only to fulfill a college science requirement
B. Only to fulfill a requirement for my major
C. Only to fulfill another requirement not mentioned above
D. To fulfill a requirement but would want to take it anyway
E. Simply because I want to--it is not a requirement

16. THE GRADE I WILL AIM FOR IN THIS COURSE IS: A. 4.0 B. 3.5 C. 3.0 D. 2.5 E. 2.0

17. THE LOWEST GRADE THAT WOULD SATISFY ME IS: A. 4.0 B. 3.5 C. 3.0 D. 2.5 E. 2.0

18. MY OVERALL COLLEGE GRADE-POINT IS: A. 3.5-4.0 B. 3.0-3.49 C. 2.5-2.99 D. 2.0-2.49 E. Below 2.0

Rate each of the following according to its value to you in learning concepts in past science or science related courses. Use the following scale.

A = not helpful B = slightly helpful C = somewhat helpful D = very helpful E = extremely helpful

19. LABORATORY WORK 20. DEMONSTRATIONS 21. FILMS 22. LECTURES 23. DISCUSSIONS
24. TEXTBOOKS 25. PROBLEM-SOLVING 26. REVIEW SESSIONS FOR EXAMS

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27. THE TYPE OF DISCUSSION WHICH I FIND TO BE THE BEST IN AIDING MY UNDERSTANDING OF A TOPIC PRESENTED IN A LECTURE OR SECTION OF A TEXTBOOK IS:

A. Quantitative with as little description and additional discussion as possible, as in mathematical derivation or proof

B. Logical and quantitative, but with a few examples given to illustrate the implications of the general principles and conclusions

C. Thoroughly discussed with a great deal of qualitative illustrations drawn from common experiences, and many examples of applications to problem situations

28. I WOULD PREFER TO HAVE THE CONTENT OF THE COURSE SELECTED IN THE FOLLOWING WAY:

A. An overview of several topics at a relatively basic level
B. Concentration on a few topics in somewhat more depth

29. WHEN ANTICIPATING AND TAKING EXAMS I AM GENERALLY

A. so tense that I often feel sick and/or my mind goes blank
B. sufficiently nervous that my abilities are often impaired
C. slightly nervous such that my performance is slightly and/or occasionally impaired
D. relaxed and unaffected by tension
E. stimulated by the tension to perform exceptionally well

30. COMPARED WITH OTHER COURSES I HAVE TAKEN, I ANTICIPATE THE DIFFICULTY OF THIS COURSE TO BE: very easy 1. 2. 3. 4. 5. very difficult

31. I ANTICIPATE THAT THIS COURSE WILL BE:

very boring 1. 2. 3. 4. 5. very interesting

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32. BASED ON MY PAST SCIENCE COURSES, MY ENJOYMENT OF SCIENCE HAS BEEN;
low 1. 2. 3. 4. 5. high

33. BASED ON MY PAST SCIENCE COURSES, MY ATTITUDE TOWARD SCIENCE IS:
don't like it 1. 2. 3. 4. 5. like it very much

34. BASED ON MY PAST SCIENCE COURSES, MY ANXIETY TOWARD LEARNING SCIENCE IS:
high 1. 2. 3. 4. 5. low

35. MY ANXIETY TOWARDS LEARNING PHYSICS IS:
high 1. 2. 3. 4. 5. low

ANSWER THE FOLLOWING QUESTIONS ONLY IF YOU ARE A PROSPECTIVE TEACHER.

36. HAVE YOU HAD YOUR SCIENCE METHODS TEACHING COURSE? A. yes B. no

37. IF YES, YOUR ENJOYMENT OF THE COURSE WAS: low 1. 2. 3. 4. 5. high

38. IF YES, I FEEL THAT MY COMPETENCE IN TEACHING SCIENCE IS: low 1. 2. 3. 4. 5. hig

39. HAVE YOU DONE YOUR STUDENT TEACHING? A. yes B. no

40. IF YES, DID YOU TEACH SOME SCIENCE?
A. No, K-3 B. No, 4-6 C. Yes, K-3 D. Yes, 4-6 E. No, special teacher

41. IF YES, HOW COMPETENT DID YOU FEEL IN TEACHING SCIENCE?
low 1. 2. 3. 4. 5. high

RATE EACH OF THE FOLLOWING ACCORDING TO ITS VALUE TO YOU IN POTENTIALLY HELPING YOU TEACH SCIENCE FROM PAST SCIENCE OR SCIENCE RELATED COURSES. USE THE FOLLOWING SCALE.

A= not helpful B= slightly helpful C= somewhat helpful D= very helpful E= extremely helpful

42. LABORATORY WORK 43. DEMONSTRATIONS FILMS 44. LECTURES 45. DISCUSSIONS

46. TEXTBOOKS . PROBLEM-SOLVING 47. RESOURCE BOOKS, MAGAZINES, ETC.

48. REVIEW SESSIONS FOR EXAMS

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49. THE DEGREE TO WHICH I ANTICIPATE DERIVING ENJOYMENT OUT OF TEACHING SCIENCE TO ELEMENTARY SCHOOL CHILDREN IS BEST DESCRIBED AS:
very little 1. 2. 3. 4. 5. very much

50. THE PERCENTAGE OF MY CLASSROOM TIME WHICH I ANTICIPATE DEVOTING TO TEACHING SCIENCE IS
A. less than 5% B. 5-10% C. 10-15% D. 15-20% E. 20% or more

51. I ANTICIPATE TEACHING THE FOLLOWING GRADE LEVELS:
A. K-1 B. 2-3 C. 4-5-6 D. 7-8 E. other

This is a copy of the Moore & Sutman "Scientific Attitude Inventory" given to the students the first and last week of the class. Coding which corresponds to the subscales in Table 2 have been added for your scrutiny.

What Is Your Attitude Toward Science?

(A Scientific Attitude Inventory)

There are some statements about science on the next few pages. Some statements are about the nature of science, some are about how scientists work. Some of these statements describe how you might feel about science. You may agree with some of the statements and you may disagree with others. That is exactly what you will be asked to do. By doing this, you will show your attitude toward science.

After you have carefully read a statement, decide whether or not you agree with it. If you agree, decide whether you agree mildly or strongly. If you disagree, decide whether you disagree mildly or strongly. Then, find the number of that statement on the answer sheet, and blacken the space by the

1 if you agree strongly.
2 if you agree mildly.
3 if you disagree mildly.
4 if you disagree strongly.

Example:

00. I would like to have a lot of money.
00. 1 ▬▬▬ 2 ▬▬▬ 3 ▬▬▬ 4 ▬▬▬
(The person who marked this example agrees strongly with the statement, "I would like to have a lot of money.")

Please respond to each statement and blacken only *one* space for each statement.

What Is Your Attitude Toward Science?

6A 1. I would enjoy studying science and using this knowledge in some scientific field.
2B 2. Anything we need to know can be found out through science.
2B 3. Scientific explanations can be made only by scientists.
3B 4. Once they have developed a good theory, scientists must stick together to prevent others from saying it is wrong.
3B 5. It is useless to listen to a new idea unless everybody agrees with the idea.
4A 6. Science may be described as being primarily an idea-generating activity.
1A 7. Scientists are always interested in improving their explanations of natural events.
3B 8. If one scientist says a theory is true, all other scientists will believe him.
5B 9. Science is so difficult that only highly trained scientists can understand it.
1A 10. A useful scientific theory may not be entirely correct, but it is the best idea scientists have been able to think up.
2B 11. We can always get answers to our questions by asking a scientist.
1B 12. There are some things which are known by science to be absolutely true.
5B 13. Most people are not able to understand the work of science.
4B 14. Today's electric appliances are examples of the really valuable products of science.
2A 15. Scientists cannot always find the answers to their questions.
1B 16. When something is explained well, there is no reason to look for another explanation.
5A 17. Most people are able to understand the work of science.
3A 18. A scientific theory is no better than the objective observations upon which it is based.
2A 19. Scientists believe that they can find explanations for what they observe by looking at natural phenomena.
6B 20. The day after day search for scientific knowledge would become boring for me.
6B 21. Scientific work would be too hard for me.
1B 22. Scientists discover laws which tell us exactly what is going on in nature.
1A 23. Scientific ideas may be said to undergo a process of evolution in their development.
4A 24. The value of science lies in its usefulness in solving practical problems.
3A 25. When one asks questions in science, he gets information by observing natural phenomena.
3A 26. A good scientist doesn't have any ideas he is not willing to change.
2A 27. Looking at natural phenomena is a most important source of scientific information.
5A 28. Public understanding of science is necessary because scientific research requires financial support through the government.
2A 29. Some questions cannot be answered by science.
5A 30. Rapid progress in science requires public support.
5B 31. Scientists do not need public support, they can get along quite well without it.
4A 32. A scientist must be imaginative in developing ideas which explain natural events.
4A 33. The value of science lies in its theoretical products.
4A 34. Ideas are one of the more important products of science.
6B 35. I do not want to be a scientist because it takes too much education.
5B 36. There is no need for the public to understand science in order for scientific progress to occur.
3A 37. When a scientist is shown enough evidence that one of his ideas is a poor one, he should change his idea.
38. All one has to do to learn to work in a
3B

scientific manner is to study the writings of great scientists.

2B 30. Before one can do anything in science, he must study the writings of the great scientists.

5A 40. People need to understand the nature of science because it has such a great affect upon their lives.

4B 41. A major purpose of science is to produce new drugs and save lives.

3A 42. One of the most important jobs of a scientist is to report exactly what his senses tell him.

2B 43. If a scientist cannot answer a question, all he has to do is to ask another scientist.

4B 44. An important purpose of science is to help man to live longer.

6A 45. I would enjoy working with other scientists in an effort to solve scientific problems.

1B 46. Scientific laws cannot be changed.

4A 47. Science is devoted to describing how things happen.

5A 48. Every citizen should understand science because we are living in an age of science.

6A 49. I may not make many great discoveries, but working in science would still be interesting to me.

4B 50. A major purpose of science is to help man live more comfortably.

3B 51. Scientists should not criticize each other's work.

2A 52. ~~His~~ senses are one of the most important tools a scientist has.

1A 53. Scientists believe that nothing is known to be true with absolute certainty.

1B 54. Scientific laws have been proven beyond all possible doubt.

6A 55. I would like to work in a scientific field.

1A 56. A new theory may be accepted when it can be shown to explain things as well as another theory.

6B 57. Scientists do not have enough time for their families or for fun.

5B 58. The products of scientific work are mainly useful to scientists, they are not useful to the average person.

6B 59. Scientists have to study too much and I would not want to be one for this reason.

6A 60. Working in a laboratory would be an interesting way to earn a living.

OPEN-ENDED WAVE QUESTIONS (TABLE 4)

Please answer the following questions as best as you can. Don't worry about your answers being exactly correct. Your own ideas are important. Thank you.

1. What is a wave?

2. Give some examples of waves.

3. What can waves do? (e.g., Describe some wave properties)

4. What common experiences do you think you understand in terms of waves? Explain.

WAVE DEFINITIONS (TABLE 5)

RESEARCH EXERCISE: Directions: Describe the following terms from your knowledge without using books, notes, etc. You may use diagrams to define or relate terms. Try to think of the terms as they relate to waves. If you are not sure of a term, then guess. If you have no idea, then write a "question mark".

1. VIBRATION

2. VELOCITY

3. FREQUENCY

4. WAVELENGTH
   a. CREST

   b. TROUGH

5. AMPLITUDE

6. TRANSVERSE WAVE

7. LONGITUDINAL WAVE
   a. COMPRESSION

   b. RAREFRACTION

8. STANDING WAVE
   a. NODES

   b. ANTINODES

9. INTERFERENCE
   a. CONSTRUCTIVE

   b. DESTRUCTIVE

10. RESONANCE

11. BEATS

12. REFLECTION

13. DIFFRACTION

14. REFRACTION

15. REVERSIBILITY

16. DOPPLER EFFECT

WAVE SKETCHES AND EXPLANATIONS (TABLES 6, 7 & 8)

WAVES

1. Given a slinky.

    a. Sketch the disturbance for a Transverse Wave.

    b. Sketch the disturbance for a longitudinal wave.

2. On the diagram, label a) crest, b)trough, c)amplitude, and d)wavelength.

3. The following involve a top view of a ripple tank.

    a. Given two barriers with different size openings. Sketch the relative degrees of diffraction for each tank. Explain.

    b. Given two wave point sources. Sketch a possible interference pattern. Explain.

    c. Given shallow water covering a plexiglass block, surrounded by deep water. Sketch how the waves migh refract. Explain.

4. Briefly explain the following.

    a. Why can you hear a sound around the corner of a hallway?

PARTS b, c, & d are used only in TABLE 8.

    b. Why are sunsets red?

    c.What travels near the speed of light in an electric circuit?

    d. How does a bonfire warm you?

WAVES

NAME_______________________________

DATE______________

SECTION____________

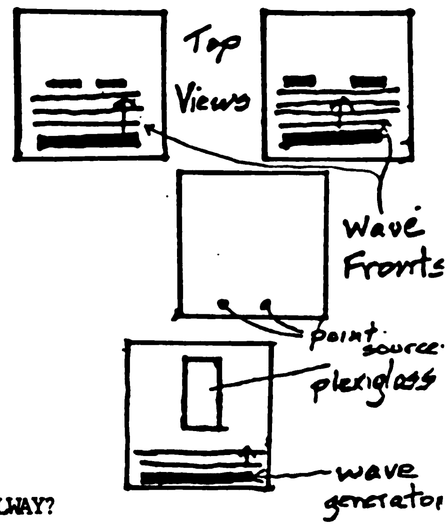
1. GIVEN A SLINKY. 

SKETCH THE DISTURBANCE FOR A TRANSVERSE WAVE.

SKETCH THE DISTURBANCE FOR A LONGITUDINAL WAVE.

2. ON THE DIAGRAM, LABEL CREST, TROUGH, AMPLITUDE, WAVELENGTH.

3. THE FOLLOWING INVOLVE A TOP VIEW OF A RIPPLE TANK.



GIVEN TWO BARRIERS WITH DIFFERENT SIZE OPENINGS. SKETCH THE RELATIVE DEGREES OF DIFFRACTION FOR EACH TANK. EXPLAIN.

GIVEN TWO WAVE POINT SOURCES. SKETCH A POSSIBLE INTERFERENCE PATTERN. EXPLAIN.

GIVEN SHALLOW WATER COVERING A PLEXIGLASS BLOCK, SURROUNDED BY DEEP WATER. SKETCH HOW THE WAVES MIGHT REFRACT. EXPLAIN.

4. BRIEFLY EXPLAIN THE FOLLOWING.
WHY CAN YOU HEAR A SOUND AROUND THE CORNER OF A HALLWAY?

WHY ARE SUNSETS RED?

WHAT TRAVELS NEAR THE SPEED OF LIGHT IN AN ELECTRIC CIRCUIT?

HOW DOES A BONFIRE WARM YOU?

5. DO YOU FEEL VERY COMPETENT IN TEACHING SCIENCE BEFORE TAKING THIS COURSE? EXPLAIN.

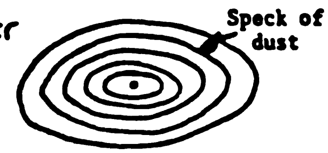
1.

2.

3.

WAVES

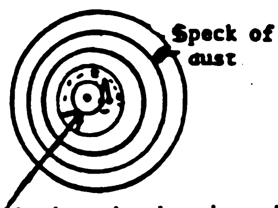
1. Water



A rock is thrown into a pool and the waves move outward. How do the waves move a tiny speck of dust that is floating on the surface of the pool?

Put a dot where you think the speck of dust will be left after the waves have passed.

2. Air



A bell rings in the air and sound waves move outward. How do they move a tiny speck of dust that is floating in the air?

Put a dot where you think the speck of dust will be left after the sound waves have passed.

3. Why does a long organ pipe make a lower note than a short organ pipe? Illustrate your answer with a drawing, if need be.

<u>SPECIAL RESEARCH EXERCISE</u> (Appendix A)

This is a copy of the Special Research Exercise given half-way through the course each term after the Sound and Light units.

SPECIAL RESEARCH EXERCISE: You may refer to your comments on benefits, etc. in your laboratory write-ups: Metrics, Waves, Shadows, Pinhole Camera, Diffraction Grating, Color Shadows, Lenses.

Please put your name, date, section, on an 8 1/2 x 11 paper. Use as many sheets as you wish. We need your thoughtful, honest impressions. Thank you.

1. Reflect on how hands-on, visual, small-group laboratory have helped your understanding of waves & sound. Refer to specific activities such as slinkies, resonance tube, ripple tank, etc. and also to specific ideas like wave type, diffraction, interference, refraction, etc.

2. Reflect on how laboratory experiences have helped your understanding of waves and light. Refer to activities such as Shadows, Pinhole Camera, Colors, Lenses, etc. and also to ideas like how light travels, Reflection & Absorption, "Fuzzy" images, Color Pigments & Color Primaries, Eye Problems, etc.

3. Has the informal, small-group laboratory environment improved your enjoyment of science and helped you in learning the concepts? Please be specific in your comments, using examples if possible like individual help, teaching analogies, time for questions, etc.

4. In developing a "Scientific Attitude" and learning science, how do the benefits of the laboratory experience compare to other aspects of this course. Please be specific in your comments, if possible referring to textbook, problem sets, lecture, etc.

NOTE IT IS NOT NECESSARY TO USE THE SUGGESTED ACTIVITIES & IDEAS IN YOUR ANSWERS. YOU USE ANY ACTIVITIES OF IDEAS OF YOUR CHOOSING.

Transfer of Learning/Teaching Skills (Appendix C)

This is a copy of the open-ended laboratory questionnaire given to the students near the last week of the class. Quotes taken from this exercise are listed under the "Transfer of Learning/Teaching Skills" section in the appendices.

RESEARCH EXERCISE: PLEASE PUT YOUR NAME, DATE AND SECTION ON AN 8 x 11 PIECE OF PAPER AND ANSWER THE FOLLOWING:

1. HOW WELL CAN YOU SUMMARIZE & COMPARE SOUND, LIGHT, HEAT AND ELECTRICITY AS WAVES? YOU MAY TRY TO USE A GRID LISTING THE 4 TYPES OF WAVES ALONG THE TOP AND LISTING THE NAMES OF WAVE PROPERTIES ALONG THE SIDE. THESE PROPERTIES MAY INCLUDE SOURCE OF WAVE, WAVELENGTH, WAVE TYPE, DOES IT DIFFRACT? REFRACT? REFLECT? ETC. ANSWER THE QUESTIONS WHERE THE COLUMNS & ROWS CROSS ON THE GRID IF YOU ARE USING ONE. SEE EXAMPLE BELOW.

2. WHAT IS THE MOST SURPRISING IDEA YOU HAVE LEARNED ABOUT WAVES? WHAT STILL SEEMS TO BE CONFUSING ABOUT WAVES? PLEASE EXPLAIN.

3. HOW HAS THE HANDS-ON, SMALL-GROUP LABORATORY EXPERIENCE INFLUENCED YOUR ATTITUDE AND SKILLS TOWARD LEARNING SCIENCE AND TOWARDS YOUR PROSPECTIVE TEACHING OF SCIENCE? PLEASE SPEND SOME TIME ON THIS ONE.

THANK YOU FOR YOUR THOUGHTFULNESS AND SINCERITY.

PLEASE RETURN AS SOON AS POSSIBLE.

LAB 2 - PROPERTIES of WAVES, MEASURING SPEED of SOUND

PRE-LAB: Read lab; define waves - both transverse and longitudinal, frequency & tension (relationship between), resonance, interference - both constructive and destructive, diffraction, reflection, refraction and the principle of reversibility. Explain the meaning of the equations 4L = (pg. 23), and V = f (pg. 22).

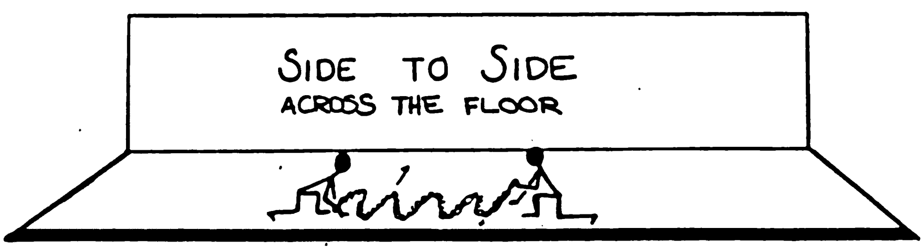
INTRODUCTION

All objects have a natural vibrational frequency, a frequency at which they prefer to vibrate. In addition, many objects have more than one preferred vibrational frequency. These natural modes of vibration are called resonant modes.

During lecture, you examined the relationship between resonant mode and frequency. In this activity, you will investigate the relationship between tension on an object and its natural vibrational frequency, and gain some experience in creating different types of waves.

PART I - TRANSVERSE & LONGITUDINAL WAVES

With a lab partner, stretch a plastic spring coil, on the floor, to a length of about two meters, making sure that each person is holding only the end of the coil. While the first partner holds one end of the coil stationary, the second partner should move the other end from side to side, creating a vibration (see diagram A).



Notice that the direction of the disturbance (the hand moving from side to side) is perpendicular to the direction that the wave travels. Waves produced in this manner are called TRANSVERSE WAVES.

The rate at which the wave is created (how fast your hand moves from side to side) is called the **frequency**. By varying the frequency, you can cause the coil to vibrate in numerous different resonant modes. At each resonant mode, the coil will appear to vibrate in segments, with one or more points along the length of the coil remaining stationary. These points, which are called **nodes**, divide the wave into segments. By counting the number of segments, you can determine which resonant mode you have created.

Set up the first four resonant modes for transverse waves. Sketch the waves in the table below.

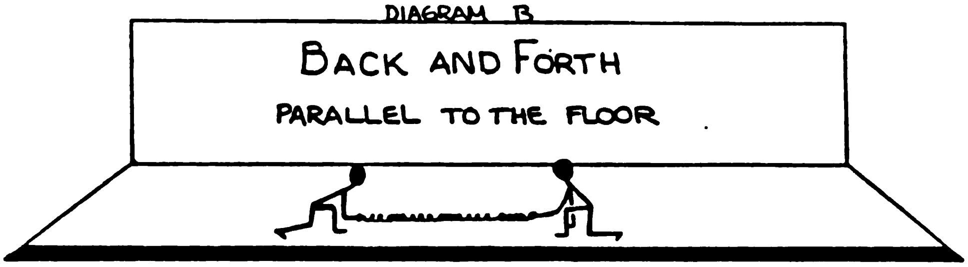
TRANSVERSE WAVES

Resonant Mode*	Number of Segments	Sketch MAKE ALL SKETCHES SAME LENGTH	Number of Wavelengths (λ)
1			
2			
3			
4			

*NOTE: In music, the first resonant mode is called the FUNDAMENTAL, while the second resonant mode is called the FIRST OVERTONE, the third resonant mode is called the SECOND OVERTONE, etc.

Now, move your hand back and forth in the same direction that the coil is stretched, you will create a "longitudinal wave". In this type of wave, the direction of disturbance is <u>parallel</u> to the direction that the wave travels (see diagram B). ***

DIAGRAM B



LONGITUDINAL WAVES

Try to set up the first three resonant modes for longitudinal waves. Sketch them in the same manner that you sketched the transverse waves.

Resonant Mode	Sketch MAKE ALL SKETCHES SAME LENGTH	Number of Wavelengths (λ).
1		
2		
3		

PART II - FREQUENCY & TENSION

At one time or another, most of us have played with a rubber band by stretching it, then plucking it to create sounds. By changing the amount of tension on the rubber band, it was possible to change the sound that was created. If you observed the rubber band closely, you could see that it vibrated at different rates to produce different sounds.

The purpose of this activity is to investigate the relationship between the tension that is placed on a vibrating object and its natural vibrational frequency. Plastic spring coils will be used instead of rubber bands, because they vibrate at a rate which can be counted.

Procedure:

1. With your lab partner, stretch the spring coil to a length of about 2m, holding only the end coils. Mark the spots where you are standing with chalk or tape.

2. Set up the first resonant mode of a transverse wave.

3. Determine the frequency of the wave by first counting the number of vibrations in 20 seconds, then dividing the number by 20 to get the number of vibrations in one second. Record your results in the table at the end of this activity.

4. To increase the tension on the coil, one lab partner should hold about 15 coils while the other partner still holds only the end coil. Make sure that the coil is stretched to the same length as before.

5. Set up the first resonant mode of vibration. Measure the frequency as you did in step 3. Record your data below.:

	Vibrations in 20 seconds	Frequency
LOW TENSION		
HIGH TENSION		

* Changing the tension also changes the mass of the coil, which has some effect on the frequency. The effect is not large enough to adversely affect the results of the experiment.

1. How did increasing the tension on the spring coil affect its natural vibrational frequency?____________________

2. If you were tuning a guitar and increasing the tension on a string, what would happen to its natural vibrational frequency?

3. How would this affect the sound that the string made?______

PART III - MEASURIING THE SPEED OF SOUND

Sounds travel as longitudinal waves. These waves require an elastic medium (a solid, liquid or gas), to transmit the energy pulses from one point to another. This was first demonstrated by Robert Boyle in the 17th century. He used an alarm clock placed inside a vacuum chamber to show that the alarm could not be heard when the air was removed from the chamber.

Sounds are longitudinal waves. These waves require an elastic medium (a solid, liquid, or gas), to transmit the energy pulses from one point to another. This was first demostrated by Robert Boyle in the 17th. Century. He used an alarm clock placed inside a vacum chamber to show that the alarm could not be heard when the air was removed from the chamber.

Early measurements of the speed of sound were made by timing the interval between the flash (which could be seen almost instantly), and the sound of a distant gun being fired. These early measurements were amazingly close to the measurements presently made by scientists. In this activity, you will measure the speed of sound in air using the principle of resonance. The following discussion and series of diagrams illustrate the use of this principle.

When we talk about speed or velocity, we are describing how far some object moves in a given amount of time, such as 55 miles per hour, 10 meters per second, or 500 feet per minute. The units on all the expressions are "distance" divided by "time", or d/t.

The velocity of a wave can be described in a similar manner using wavelength, which is a measure of how far the wave moves during one cycle (i.e. distance), and period, which is the time required to complete one cycle. Starting with the general equation for velocity (V),

$$V = \text{DISTANCE}/\text{TIME}$$

we can substitute wavelength (λ) for distance, and period (T) for time, and still have a valid expression:

$$V = \lambda \text{ (usually in cm)} / T \text{ (seconds)}$$

The units are still distance/ time . However, period and frequency are reciprocals, that is T = 1/f. If we substitute 1/f in the velocity equation, the result is :

$$V = \lambda / \tfrac{1}{f} \quad \text{OR} \quad V = \lambda f$$

Therefore if we can determine the frequency and wavelength of a particular wave, we can calculate its velocity.

We will use a tuning fork of known frequency and determine the corresponding wavelength by measuring the length of an air column that is found to resonate with the with the tuning fork. The relationship between the wavelength and the length of the air column can be reasoned as follows: Suppose you hold a vibrating tuning fork near the end of a hollow tube with length ".", which is closed at the opposite end (Figure 1).

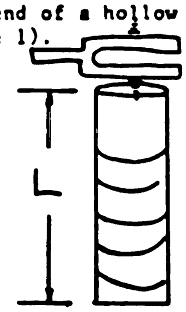


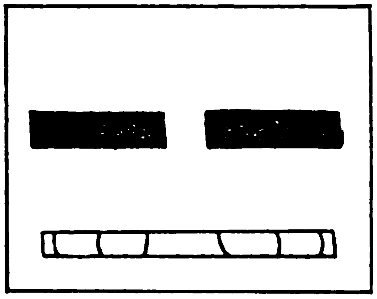
FIGURE 1

B. Plane Waves

Set up the straight wave generator in the ripple tank. Adjust the wave generator until clear images of waves appear on the surface of the lab table. Vary the speed (frequency) of the motor and notice the change in wavelength of the waves. Sketch and label the wave pattern in the space below. Then place a paraffin barrier about 15cm in front of the wave generator and note its effect on the wave pattern. Sketch this pattern also.

PART V - DIFFRACTION OF WAVES AND INTERFERENCE PATTERNS

Using a straight wave generator set up the ripple tank and arrange the paraffin blocks as shown in Figure 2.3. Keep the paraffin blocks about 10-15 cm away from the wave generator. Place the blocks so that the straight waves strike them head-on. Arrange them so that the size of the opening is about 4-5 cm. Turn on the wave generator. Observe and sketch the wave pattern.



2.3

PART VI - DIFFRACTION AND SLIT WIDTH

The bending of waves as they pass through an opening is called "diffraction". Diffraction occurs whenever a wave passes the edge of an object. Let's now pass waves through the opening and see if there are any relationships between the amount of diffraction and the size of the opening. Start the generator and adjust the speed of the motor so that the wavelength of the water waves is fairly long (low frequency). Keeping the wavelength constant, make the opening between the blocks increasingly small and observe the diffraction of the waves.

1. When is the diffraction greater?____________________________

2. What kind of wave emerges from the opening when it is very small?(point or plane waves)____________________________

SKETCHES

PART VII - DIFFRACTION & WAVELENGTH

Let's explore the relationship between the amount of diffraction and the wavelength of waves. Adjust the paraffin blocks so that the opening is 3cm. Adjust the speed of the motor so that the wavelength is quite long. While you keep the width of the opening constant, shorten the wavelength of the waves in steps by increasing the frequency of the wave generator.

1. What do you observe about the amount of diffraction as the wavelength is shortened?____

2. When is the diffraction most pronounced?______________________

3. When is it least pronounced?________________________________

SKETCHES

Applications of the relationship between diffraction and wavelength are found in radio transmission. Since radio wavelengths are rather long they easily "bend" around buildings and other objects in their path.

PART VIII - INTERFERENCE PATTERNS

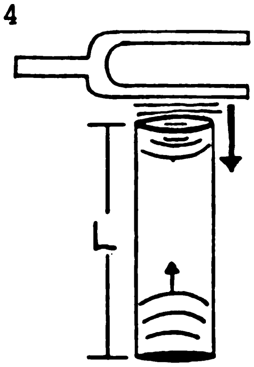
Based upon the above experiences you can now begin to explore interference patterns. Arrange two beads on the wave generator so that two point waves about 10cm apart will be created. Adjust the wave generator to produce waves with long wavelengths. Observe the pattern produced by the point waves.

1. Are there areas of agitation and areas where the water is relativelly undisturbed?____

2. Explain why the pattern appears as it does.____________________

Try changing the wavelength of the waves.

3. Does the pattern change?____________________ How?______________



The vibrating tines of the tuning fork send out small pulses of air rapidly down the tube. This wave goes down the tube, bounces off the closed end and comes back up again (Figure 2). If the length of the tube is such that the pulse gets back up to the top of the tube at exactly the right time to catch the tine of the tuning fork as it moves upward, then this air pulse and the tine of the tuning fork move together (Figure 3).

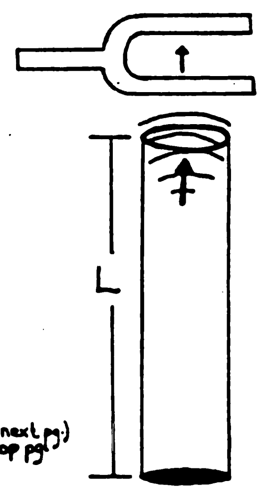
(Figure 2)

This results in constructive interference because the two vibrations (the one fom the tube and the one from the tuning fork) reinforce each other. When the tine vibrates downward again it sends down another pulse which produces more constructive interference coming back up. This sequence of events, repeating itself over and over at the same frequency as the vibration of the tuning fork, is called "resonance".

It results in a large increase in the intensity of the sound. To obtain this resonant condition the tube must, of course, be of just the right length.

If the tube is not the right length, the pulses of air come back up the tube and meet the tuning fork as it moves downward. In this case, the tine moving downward and the wave coming back up the tube oppose each other, resulting in "destructive interference".

Let's return to the example of resonance. Since the sound travels down the tube and back up in time to "catch" the tine of the tuning fork moving from down to up, the sound must make this trip of two lengths of the tube (down and back up) in one-half of a total cycle of vibration of the tuning fork. (In one vibration the tine of the tuning fork starts at the top, moves down and back up again to where it started, to complete the full cycle.) Thus, the sound pulse moves twice the length (2L) of the tube in one-half of a vibration. This means it would move the equivalent of four times the length (4 L) of the tube in one complete vibration or cycle. Therefore, when resonance occurs, the length of the tube multiplied by four is the distance that a sound pulse will travel in one complete vibration, or one wavelength. *** (see next pg. top pg) This distance multiplied by the frequency of the tuning fork (a number stamped on the base of each fork) should give the distance sound will travel in one second.



(Figure 3)

*** NOTE: The formula $4L = \lambda$ or $L = 1/4\lambda$ is true for tubes with one end closed.

Since we do not know in advance the length of the tube necessary to cause resonance, we use a tube with both ends open which is partially immersed in water. By raising or lowering the tube, the effective length of the tube ("L") the distance from the opening to the surface of the water, can be easily varied (Figure 4).

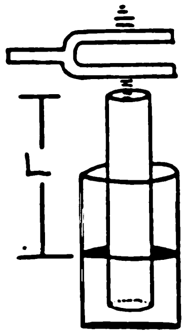


FIGURE 4

Imagine that when you were working with the spring coil you had moved your hand back and forth at the same rate as the coil was vibrating. You would then observe an increase in the intensity of the vibrations of the coil. When this happens, we say **resonance mode** has occurred. This same effect is characteristic of sound waves, except that we hear an increase in loudness rather than observing an increase in vibration.

PROCEDURE

Your lab instructor will provide a large test tube, a plastic tube open at both ends, meter sticks, and a supply of tuning forks of differing frequencies.

Fill the large test tube about 3/4 full of water. Insert the plastic tube into the test tube. Strike the tuning fork against the heel of your shoe then hold it over the plastic tube with the tines of the fork about 2cm above the tube. Hold the fork in this same position above the tube with one hand and raise the tube out of the water with the other.

As the tube is raised, a position will be found where the sound becomes louder and kind of "booms" out. What causes this to occur? ____

____

____

Measure the effective length ("L") of the tube. Record L and the frequency of the tuning fork in the table below. Repeat the procedure two or three times and calculate an average to obtain a more reliable measure of L. Calculate the speed of sound using $v = f\lambda$.

1. How well do your results compare with the accepted value for the speed of sound in air (330m/sec)?____________________________

2. Why might your results differ?____________________________

Obtain a tuning fork with a different frequency and determine L for the new frequency. Record this data also. Calculate the speed of sound.

3. How does this value compare to that obtained using the first fork?____________________________

4. Does the speed of sound in air depend on the frequency of the tuning fork?____________________________

	LENGTH L_1	LENGTH L_2	LENGTH L_3	AVE. LENGTH $\frac{L_1+L_2+L_3}{3}$	VELOCITY $v = F(4L_{average})$
Trial I (First tuning fork) F=______					
Trial II (Second tuning fork) F=______					

PART IV - WAVE PROPERTIES IN A RIPPLE TANK

Waves having varying characteristics and properties can be found everywhere in the universe, ranging from gamma rays of minute wavelength emitted by nuclear particles to the immense fluctuations in clouds of dust scattered thinly between the stars. Problems solved by the study of waves in one medium can be applied, with appropriate modification, to those in other media. Thus, by learning how waves of one kind behave, the experimenter learns what behavior to expect of other waves.

A ripple tank is an excellent means of studying the behavior of waves. The ripple tank projects an image of waves in the water onto the paper below the tank. These images will help you make observations and measurements related to the waves. Based upon these observations and measurements you should be able to determine some patterns or relationships in wave motion. The important aspect of these investigations is to provide you with a first-hand opportunity to observe wave phenomena.

Throughout these activities you should describe in writing what you observe and DRAW PICTURES of the kinds of patterns you see.

PROCEDURES

I. WAVE CHARACTERISTICS:

A. Point Waves

Set up a point wave generator by inserting a bead into the center hole of the wooden bar. Adjust the height of the wave generator until the tip of the bead just touches the surface of the water. Turn on the motor and observe the wave pattern. Vary the speed of the motor, i.e. the frequency of the waves, and observe the changes in wavelength. Sketch and label the wave pattern in the space below.

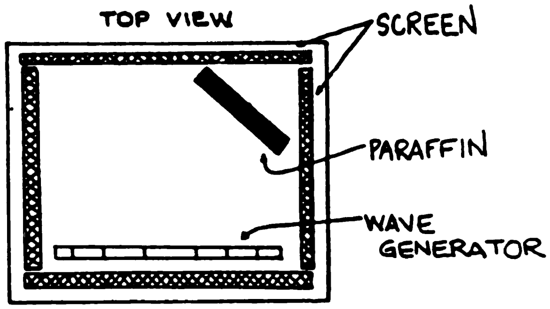
Place a paraffin block on its edge about 15cm from the point wave generator and observe the effect on the wave pattern. Sketch and label the wave pattern in the space below.

PART IX - REFLECTION OF WAVES

Waves which bounce off an obstacle or barrier in their path and travel in a different direction are said to be "reflected".

Wave reflection is utilized in radar and sonar, in which waves are used to locate objects.

Place a paraffin barrier in the tank so that it is at an angle to the wave's direction of movement as shown at the right. Now generate plane waves from the end toward the barrier and observe what happens.



1. How are the waves reflected?____

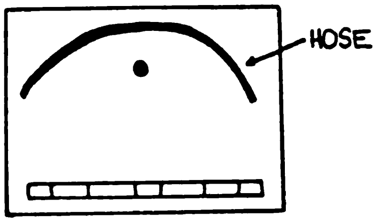
2. What happens?____

Sketch and label the wave patterns in the diagram above.

PART X - REFLECTION OF WAVES

Place the piece of hose in the ripple tank so that it presents a curved front to oncoming plane waves.

Generate straight waves toward the concave hose surface and observe the reflected pulses carefully. Sketch the wave pattern on the diagram.

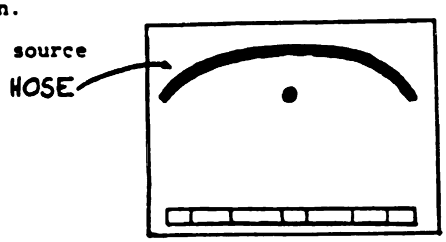


As far as the water waves are concerned, a barrier placed in the tank acts as a mirror. When the barrier is curved, it acts like a curved mirror and reflects all the oncoming waves through the same point (focus).

Shut off the wave generator. Tap the water at the point where the straight waves came together after reflection. Observe how the circular pulse is reflected.

Illustrate the "reversibility" of waves on the diagram below. Reversibility means that a wave that follows a particular path in one direction will follow an identical path if it travels in the opposite direction.

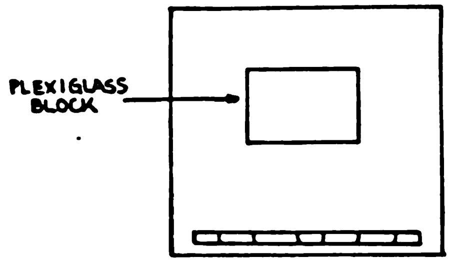
**NOTE: Show the wave direction from its source with arrows.



PART XI - REFRACTION OF WAVES

When a wave passes from one substance to another, it bends. Changes also occur when the wave is traveling through only one substance, if the nature of that substance changes. For example a wave that is moveing through deep water will bend if it passes a point where the depth of the water changes. This is called "refraction".

Set up the ripple tank with a flat plexi-glass plate in the tank as shown in Figure at the right.



Start the plane wave generator and adjust it to a low frequency. The wave front should be parallel to the front edge of the glass plate. Observe the waves in the shallow medium and compare them with the waves in the deeper medium. Sketch your observations.

SKETCHES:

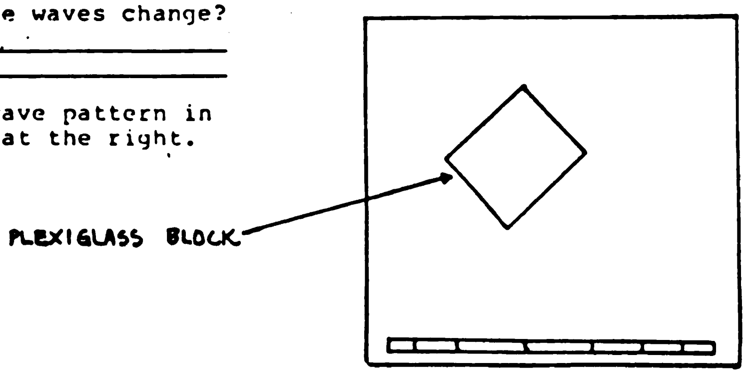
Turn the plexiglass plate so that the waves encounter it at an angle as shown in the figure at the right.

1. How do the waves change?

____

____

Sketch the wave pattern in the diagram at the right.



APPENDIX F: DATA TABLES

Appendix F contains a listing of the complete Data Tables that were used and explained in Chapters 3 and 4.

DATA TABLES LISTING

Table 1: General Student Background (Background & Attitude Questionnaire) Page 261

Table 2: Attitudes Toward Learning & Teaching Science (Backgound & Attitude Questionnaire) Page 262

Table 3: Moore & Sutman Scientific Attitude Inventory (SAI Survey) Page 263

Table 4: Open-ended Wave Questions (Open-ended Wave Questions) Page 265

Table 5: Wave Definitions (Wave Definitions Exercise) Page 266

Table 6: Wave Patterns & Explanations (Wave Sketches & Explanations Exercise) Page 268

Table 7: Spring Eight Week Follow-up (Wave Sketches & Explanations Exercise) Page 269

Table 8: Wave Knowledge Transfer (Wave Sketches & Explanations Exercise) Page 271

Table 9: Science Learning & Teaching Skills (Background & Attitude Questionnaire) Page 272

TABLE 1 : GENERAL STUDENT BACKGROUND

STUDENT-QUESTIONNAIRE RESPONSES ARE GIVEN IN PERCENTAGES.

Q-1: MAJOR? 88.9 Elementary Education
5.6 Special Education 5.6 Other

Q-2: CLASS? 57.4 Seniors 29.6 Juniors
9.3 Sophomores 3.7 Special Student

Q-14: CLASSIFY YOUR ELEMENTARY SCIENCE ACTIVITY.

33.3 Much Activity 51.9 Little Science Activity
14.8 Little or No Science

Q-15: WHY DID YOU ENROLL IN THIS CLASS?

72.2 A Major or College Requirement
25.9 A Requirement, but also wanted to
1.9 No Requirement, but wanted to

Q-18: OVERALL GRADE POINT AVERAGE

3.5-4.00: 14.8 2.5-2.99: 37.0
3.0-3.49: 35.2 2.0-2.49: 13.0

Q-36: 40.4% of PHS 203 students had their Science Methods Course with the following influences:

Q-37: DEGREE TO WHICH SCIENCE METHODS CLASS WAS ENJOYED

low	2	3	4	high
15.4	11.5	23.1	30.8	19.2

Q-38: DEGREE OF SCIENCE-TEACHING COMPETENCE FELT AFTER SCIENCE METHODS CLASS

low	2	3	4	high
4.8	28.6	28.6	28.6	9.4

Q-39 & 40: 20 % of the students had completed STUDENT TEACHING in which 23.1% taught science in K-3 & 76.9% in 4-6

Q-41: DEGREE OF SCIENCE-TEACHING COMPETENCE FELT AFTER STUDENT TEACHING EXPERIENCE

	LOW	2	3	4	HIGH
pretest	7.7	0.0	15.4	46.2	30.8
posttest	14.3	14.3	7.1	57.1	7.1

TABLE 2: MOORE & SUTMAN SCIENTIFIC ATTITUDE INVENTORY

Mean Differences between pretests & postests are shown for each subscale.

1A. SCIENTIFIC LAWS/THEORIES ARE APPROXIMATIONS OF THE TRUTH AND SUBJECT TO CHANGE.

pretest	10.2105	shift -.1930
posttest	10.4035	increases 1a attitude

1B. SCIENTIFIC LAWS/THEORIES ARE UNCHANGED TRUTHS

pretest	10.3772	shift -.0526
posttest	10.4298	increases 1a attitude

2A. OBSERVATION IS THE BASIS OF SCIENCE. SCIENCE CAN ANSWER ONLY SOME QUESTIONS ABOUT NATURAL PHENOMENA.

pretest	11.0702	shift +.1053
posttest	10.9649	increases 2b attitude

2B. AUTHORITY IS THE BASIS OF SCIENCE. SCIENCE CAN PROVIDE CORRECT ANSWERS TO ALL QUESTIONS.

pretest	11.0175	shift -.3333
posttest	11.3509	increases 2a attitude

3A. THE SCIENTIFIC MANNER INVOLVES INTELLECTUAL HONESTY, OBJECTIVE OBSERVATIONS, AND A WILLINGNESS TO CHANGE ONE'S MIND ON THE BASIS OF SUFFICIENT EVIDENCE.

pretest	9.0702	shift -.9825
posttest	10.0526	increases 3a attitude

3B. THE SCIENTIFIC MANNER INVOLVES KNOWING ALL SCIENTIFIC TRUTHS AND BEING ABLE TO TAKE THE SIDE OF OTHER SCIENTISTS.

pretest	13.1140	shift -.0614
posttest	13.1754	increases 3a attitude

4A. THE VALUE OF SCIENCE IS IN GENERATING IDEAS/THEORIES. IT IS DEVOTED TO EXPLAINING NATURAL PHENOMENA.

pretest	9.0439	shift -.2368
posttest	9.2807	increases 4a attitude

TABLE 2:(Cont'd) MOORE & SUTMAN SCIENTIFIC ATTITUDE INVENT.
4B. THE VALUE OF SCIENCE IS IN DEVELOPING PRACTICAL USES/ TECHNOLOGIES. ITS DEVOTED TO SERVING HUMANKIND.

pretest	5.4561	shift +.2105
posttest	5.2456	increases 4b attitude

5A. SCIENTIFIC PROGRESS REQUIRES PUBLIC SUPPORT, AWARENESS AND UNDERSTANDING.

pretest	9.7807	shift -.1053
posttest	9.8860	increases 5a attitude

5B. THE PUBLIC DOES NOT NEED TO UNDERSTAND SCIENCE. SCIENCE DOES NOT AFFECT THE PUBLIC.

pretest	11.3860	shift +.0965
posttest	11.2895	increases 5b attitude

6A. I WOULD LIKE TO DO SCIENTIFIC WORK. ITS INTERESTING AND REWARDING.

pretest	7.6667	shift -.2105
poststest	7.8772	increases 6a attitude

6B. I WOULD NOT LIKE TO DO SCIENTIFIC WORK. ITS DULL, TOO HARD, AND TIME-CONSUMING.

pretest	9.5351	shift -.4737
posttest	10.0088	increases 6a attitude

EMO SCALE: EMOTIONAL REACTION TO SCIENCE
THIS IS THE SUM OF SCALES 4AB + 5AB + 6AB

pretest	52.8684	shift -.7193
posttest	53.5877	more positive toward science

INT SCALE: KNOWLEDGE ABOUT THE NATURE OF SCIENCE
THIS IS THE SUM OF SCALES 1AB + 2AB + 3AB

pretest	64.8596	shift -1.5175
posttest	66.3772	more knowledgable about science

TOTAL: THIS IS THE SUM OF 1AB + 2AB + 3AB + 4AB + 5AB + 6AB

pretest	117.7281	shift -2.2368
posttest	119.9649	

TABLE 3: ATTITUDES TOWARD LEARNING & TEACHING SCIENCE

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: GENERALLY 1-5 = MOST NEGATIVE TO MOST POSITIVE
REFER TO EACH QUESTION FOR PARAMETERS

	1	2	3	4	5
Q-30: COURSE DIFFICULTY	VERY DIFFICULT				VERY EASY
pretest	20.4	50.0	25.9	3.7	0.0
posttest	5.6	29.6	37.0	22.2	5.6
Q-31:COURSE INTEREST	VERY BORING				VERY INTERESTING
pretest	1.9	0.0	35.2	42.6	20.4
posttest	1.9	1.9	14.8	42.6	38.9
Q-32: SCIENCE ENJOYMENT	LOW				HIGH
pretest	16.7	16.7	33.3	16.7	16.7
posttest	1.9	7.4	13.0	46.3	31.5
Q-33: SCIENCE ATTITUDE	DON'T LIKE				LIKE VERY MUCH
pretest	13.0	16.7	40.7	16.7	13.0
posttest	1.9	7.4	13.0	53.7	24.1
Q-34: SCIENCE ANXIETY	HIGH				LOW
pretest	27.8	24.1	24.1	16.7	7.4
posttest	0.0	11.1	29.6	38.9	20.4
Q-35: PHYSICS ANXIETY	HIGH				LOW
pretest	37.0	31.5	16.7	13.0	1.9
posttest	1.9	11.1	16.6	59.3	11.1

Q-49: ANTICIPATED ENJOYMENT OF TEACHING SCIENCE TO CHILDREN

	VERY LITTLE				VERY MUCH
pretest	0.0	5.9	21.6	51.0	21.6
posttest	0.0	5.9	11.2	45.1	37.3

Q-50: ANTICIPATED % OF TIME DEVOTED TO TEACHING SCIENCE

	<5%	5-10%	10-15%	15-20%	>20%
pretest	0.0	17.6	35.3	27.5	19.6
posttest	0.0	6.0	28.0	44.0	22.0

Q-39: STUDENTS WHO HAVE DONE STUDENT TEACHING WERE 20%
Q-40: OF THESE, 23.1% TAUGHT SCIENCE IN K-3 & 76.9% IN 4-6
Q-41: DEGREE OF COMPETENCE FELT AFTER TEACHING SCIENCE.

	LOW	2	3	4	HIGH
pretest	7.7	0.0	15.4	46.2	30.8
posttest	14.3	14.3	7.1	57.1	7.1

TABLE 4: OPEN-ENDED WAVE QUESTIONS

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
Q-1: WHAT IS A WAVE?					
pretest	1.7	3.4	10.3	13.8	70.8
posttest	48.2	37.5	10.7	1.8	1.8
Q-2: GIVE SOME EXAMPLES OF WAVES.					
pretest	93.1	0.0	5.2	0.0	1.7
posttest	92.9	0.0	7.1	0.0	0.0
Q-3: WHAT CAN WAVES DO?(E.G. DESCRIBE SOME WAVE PROPERTIES)					
pretest	12.1	6.9	8.6	17.2	55.2
posttest	75.0	14.3	7.1	3.6	0.0
Q-4: WHAT COMMON EXPERIENCES DO YOU THINK YOU UNDERSTAND IN TERMS OF WAVES? EXPLAIN.					
pretest	29.3	6.9	38.0	13.8	12.0
posttest	76.8	16.1	7.1	0.0	0.0

TABLE 5: WAVE DEFINITIONS

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
Q-1: VIBRATION					
pretest	8.6	5.2	19.0	19.0	48.7
posttest	60.7	28.6	5.4	5.3	0.0
Q-2: VELOCITY					
pretest	29.3	25.9	13.7	5.2	25.9
posttest	92.9	1.8	1.8	3.5	0.0
Q-3: FREQUENCY					
pretest	15.5	29.3	10.4	15.5	29.3
posttest	94.6	1.8	0.0	1.8	1.8
Q-4a: CREST					
pretest	77.6	1.7	8.7	3.4	8.6
posttest	100.0	0.0	0.0	0.0	0.0
Q-4b: TROUGH					
pretest	72.4	3.4	15.6	1.7	6.9
posttest	100.0	0.0	0.0	0.0	0.0
Q-5a: AMPLITUDE					
pretest	8.6	5.2	31.0	10.4	44.8
posttest	82.1	5.4	3.6	1.8	7.1
Q-5b: WAVELENGTH					
pretest	17.2	1.7	65.6	5.2	10.4
posttest	62.5	3.6	32.5	1.8	0.0
Q-6: TRANSVERSE WAVE					
pretest	15.6	5.2	55.1	3.4	20.7
posttest	91.1	7.1	1.8	0.0	0.0
Q-7a: LONGITUDINAL WAVE: COMPRESSION					
pretest	8.6	13.8	46.6	1.7	29.3
posttest	94.6	1.8	1.8	0.0	1.8
Q-7b: LONGITUDINAL WAVE: RAREFACTION					
pretest	8.6	8.6	67.3	0.0	15.5
posttest	94.6	1.8	1.8	0.0	1.8
Q-8a: STANDING WAVE: NODES					
pretest	5.2	8.6	63.8	1.7	20.7
posttest	85.8	8.9	1.7	1.8	1.8
Q-8b: STANDING WAVE: ANTINODES					
pretest	0.0	5.2	74.1	1.7	19.0
posttest	73.2	8.9	14.3	3.6	0.0

TABLE 5 (Cont'd) WAVE DEFINITIONS

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
Q-9a: INTERFERENCE: CONSTRUCTIVE					
pretest	6.9	10.3	39.7	6.9	36.2
posttest	89.3	8.9	0.0	0.0	1.8
Q-9b: INTERFERENCE: DESTRUCTIVE					
pretest	6.9	8.6	46.6	6.9	31.0
posttest	87.5	7.1	1.8	0.0	3.6
Q-10: RESONANCE					
pretest	0.0	0.0	72.4	0.0	27.6
posttest	80.4	14.3	1.8	3.5	0.0
Q-11: BEATS					
pretest	0.0	1.7	58.6	0.0	39.7
posttest	55.4	19.7	12.2	7.1	5.3
Q-12: REFLECTION					
pretest	12.1	19.0	39.6	13.8	15.5
posttest	89.3	1.8	3.5	5.4	0.0
Q-13: DIFFRACTION					
pretest	0.0	3.4	72.5	6.9	17.2
posttest	80.4	5.4	8.9	3.5	1.8
Q-14: REFRACTION					
pretest	1.7	12.1	72.4	0.0	13.8
posttest	75.0	10.7	8.9	1.8	3.6
Q-15: REVERSIBILITY					
pretest	1.7	5.2	67.2	6.9	19.4
posttest	66.1	7.1	25.0	0.0	1.8
Q-16: DOPPLER EFFECT					
pretest	1.7	6.9	69.0	3.4	19.0
posttest	67.9	16.1	1.7	12.5	1.8

TABLE 6: WAVE PATTERNS & EXPLANATIONS

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct; 0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
GIVEN SLINKY:					
Q-1a: CREATE TRANSVERSE DISTURBANCE					
pretest	0.0	5.2	56.9	1.7	36.2
posttest	67.9	12.5	5.4	5.3	8.9
Q-1b: CREATE LONGITUDINAL DISTURBANCE					
pretest	0.0	3.4	55.2	0.0	41.4
posttest	69.6	5.4	8.9	5.4	10.7
LABEL WAVE FEATURES:					
Q-2a: CREST					
pretest	84.5	0.0	10.3	0.0	5.2
posttest	98.2	0.0	1.8	0.0	0.0
Q-2b: TROUGH					
pretest	74.1	0.0	19.0	0.0	6.9
posttest	98.2	0.0	1.8	0.0	0.0
Q-2c: AMPLITUDE					
pretest	24.1	1.7	17.3	3.4	53.5
posttest	96.4	0.0	3.6	0.0	0.0
Q-2d: WAVELENGTH					
pretest	41.4	1.7	19.0	3.4	34.5
posttest	94.6	0.0	1.8	3.6	0.0
RIPPLE TANK: SKETCH & EXPLAIN					
Q-3a: COMPARE DIFFRACTION: DIFFERENT SIZE OPENINGS					
pretest	1.7	0.0	81.0	5.2	12.1
posttest	67.9	8.9	10.7	10.7	1.8
Q-3b: SKETCH INTERFERENCE: TWO POINT SOURCES					
pretest	0.0	1.7	69.0	1.7	27.6
posttest	44.7	32.1	12.5	8.9	1.8
Q-3c: REFRACTION: DEEP TO SHALLOW WATER					
pretest	0.0	5.2	72.4	0.0	22.4
posttest	64.3	14.3	10.7	8.9	1.8
GIVE BRIEF EXPLANATION:					
Q-4a: HEARING A SOUND AROUND THE CORNER OF A HALLWAY					
pretest	8.6	24.1	19.1	10.3	37.9
posttest	80.4	14.2	3.6	1.8	0.0

TABLE 7: SPRING EIGHT WEEK FOLLOW-UP

WAVE PATTERNS & EXPLANATIONS: KNOWLEDGE RETENTION
Pretests (n = 35), Posttests (n = 33), & FOLLOW-UP (n = 31)
FREQUENCY DISTRIBUTION IN PERCENTAGES.

RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
GIVEN SLINKY:					
Q-1a: CREATE TRANSVERSE DISTURBANCE					
pretest	0.0	5.7	60.0	2.9	35.4
posttest	63.6	18.2	6.0	6.1	6.1
FOLLOW-UP	64.5	6.5	3.2	3.3	6.5
Q-1b: CREATE LONGITUDINAL DISTURBANCE					
pretest	0.0	0.0	62.9	0.0	37.1
posttest	69.7	9.1	12.1	3.0	6.1
FOLLOW-UP	67.7	6.5	3.3	12.9	9.7
LABEL WAVE FEATURES:					
Q-2a: CREST					
pretest	74.3	0.0	17.1	0.0	8.6
posttest	97.0	0.0	3.0	0.0	0.0
FOLLOW-UP	100.0	0.0	0.0	0.0	0.0
Q-2b: TROUGH					
pretest	57.1	0.0	31.4	0.0	11.5
posttest	97.0	0.0	3.0	0.0	0.0
FOLLOW-UP	96.8	0.0	3.2	0.0	0.0
Q-2c: AMPLITUDE					
pretest	20.0	0.0	22.9	5.7	51.4
posttest	93.9	0.0	6.1	0.0	0.0
FOLLOW-UP	87.0	0.0	3.2	3.3	6.5
Q-2d: WAVELENGTH					
pretest	25.7	0.0	31.4	5.7	37.2
posttest	93.9	0.0	6.1	0.0	0.0
FOLLOW-UP	96.8	0.0	0.0	3.2	0.0
RIPPLE TANK: SKETCH & EXPLAIN					
Q-3a: COMPARE DIFFRACTION: DIFFERENT SIZE OPENINGS					
pretest	2.9	0.0	85.7	2.9	8.6
posttest	60.6	12.1	12.2	12.1	3.0
FOLLOW-UP	61.3	16.1	6.5	12.9	3.2
Q-3b: SKETCH INTERFERENCE: TWO POINT SOURCES					
pretest	0.0	0.0	82.9	0.0	17.1
posttest	42.4	33.3	15.2	6.1	3.0
FOLLOW-UP	32.3	48.2	3.3	6.5	9.7

TABLE 7: (Continued) SPRING EIGHT WEEK FOLLOW-UP

Q-3c: REFRACTION: DEEP TO SHALLOW WATER

pretest	0.0	2.9	80.0	0.0	17.1
posttest	63.3	18.2	12.2	3.0	3.0
FOLLOW-UP	58.0	12.9	6.5	12.9	9.7

GIVE BRIEF EXPLANATION:

Q-4a: HEARING A SOUND AROUND THE CORNER OF A HALLWAY

pretest	14.3	8.6	22.9	11.4	42.8
posttest	75.8	18.2	3.0	3.0	0.0
FOLLOW-UP	71.0	19.3	0.0	9.7	0.0

TABLE 8: WAVE KNOWLEDGE TRANSFER

Pretests & Transfers: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 2 = correct; 1 = inferred correct;
0 = no response; -1 = inferred incorrect; -2 = incorrect

	2	1	0	-1	-2
GIVE BRIEF EXPLANATION:					
Q-4b: LIGHT					
pretest	0.0	0.0	54.3	8.6	37.1
TRANSFER	41.9	38.7	0.0	12.9	6.5
Q-4c: ELECTRICITY					
pretest	0.0	0.0	60.0	2.9	37.1
TRANSFER	35.5	29.0	3.7	6.5	19.3
Q-4d: HEAT					
pretest	5.7	5.7	37.1	14.4	37.1
TRANSFER	100.0	0.0	0.0	0.0	0.0
Q-1a: WATER WAVE					
pretest	0.0	0.0	17.1	0.0	82.9
TRANSFER	80.5	3.3	9.7	0.0	6.5
Q-1b: SPECK MOVEMENT					
pretest	0.0	2.9	20.0	2.9	74.2
TRANSFER	80.5	0.0	13.0	0.0	6.5
Q-2a: AIR WAVE					
pretest	0.0	0.0	40.0	2.9	57.1
TRANSFER	32.3	3.2	16.1	9.7	38.7
Q-2b: SPECK MOVEMENT					
pretest	0.0	8.6	40.0	0.0	51.4
TRANSFER	35.5	0.0	16.1	6.5	41.9
Q-3: WAVE & PIPE LENGTH					
pretest	0.0	2.9	34.3	42.8	20.0
TRANSFER	35.5	38.8	13.0	9.7	6.5

TABLE 9: SCIENCE LEARNING & TEACHING SKILLS

RATING LEARNING & TEACHING ACTIVITIES FORM BACKGROUND-ATTITUDE QUESTIONNAIRE

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES RESPONSES: 1 = not helpful; 2 = slightly helpful; 3 = somewhat helpful; 4 = very helpful; 5 = extremely helpful.

EVALULATION OF LEARNIING ACTIVITIES BY STUDENTS BASED ON THEIR PAST SCIENCE EXPERIENCES.

	1	2	3	4	5
LEARNING:					
Q-19: LABORATORY WORK					
pretest	3.7	11.1	33.3	33.3	18.5
posttest	0.0	5.6	7.4	42.6	44.4
Q-20: DEMONSTRATIONS: LECTURE & LABORATORY					
pretest	1.9	13.0	20.4	44.4	20.4
posttest	0.0	0.0	14.8	44.4	40.7
Q-21: FILMS					
pretest	1.9	29.6	48.1	16.7	3.7
posttest	11.5	15.4	38.5	25.0	9.6
Q-22: LECTURES					
pretest	0.0	7.4	27.8	57.4	7.4
posttest	0.0	5.6	35.2	53.7	5.6
Q-23: DISCUSSIONS					
pretest	0.0	5.6	35.2	46.3	13.0
posttest	0.0	1.9	35.2	42.6	20.4
Q-24: TEXTBOOKS					
pretest	0.0	14.8	50.0	29.6	5.6
posttest	1.9	11.3	34.0	47.2	5.7
Q-25: PROBLEM SETS					
pretest	1.9	17.0	37.7	30.2	13.2
posttest	0.0	5.6	38.9	44.4	11.1
Q-26: REVIEWS PRIOR TO EXAMS					
pretest	0.0	7.4	35.2	27.8	29.6
posttest	1.9	1.9	3.8	28.3	64.2

TABLE 9: (Cont'd) SCIENCE LEARNING & TEACHING SKILLS

RATING LEARNING & TEACHING ACTIVITIES FROM BACKGROUND-ATTITUDE QUESTIONNAIRE

Pretests & Posttests: FREQUENCY DISTRIBUTION IN PERCENTAGES
RESPONSES: 1 = not helpful; 2 = slightly helpful; 3 = somewhat helpful; 4 = very helpful; 5 = extremely helpful.

POTENTIAL VALUE OF TEACHING ACTIVITIES PERCEIVED BY PROSPECTIVE-TEACHING STUDENTS

	1	2	3	4	5
LABORATORY APPROACH					
pretest	0.0	12.2	28.6	38.8	20.4
posttest	0.0	3.8	45.8	42.3	48.1
Q-43: DEMONSTRATIONS & FILMS					
pretest	0.0	2.0	26.0	54.0	18.0
posttest	0.0	5.8	7.7	44.2	42.3
Q-44: LECTURES					
pretest	0.0	12.0	42.0	40.0	6.0
posttest	1.9	17.3	48.1	26.9	5.8
Q-45: DISCUSSIONS					
pretest	0.0	6.0	30.0	48.0	16.0
posttest	0.0	5.9	35.3	39.2	19.6
Q-46: TEXTBOOKS					
pretest	0.0	12.0	32.0	42.0	14.0
posttest	1.9	9.6	32.7	42.3	13.5
Q-47: RESOURCE BOOKS, MAGAZINES, ETC					
pretest	0.0	12.0	18.0	50.0	20.0
posttest	3.9	23.5	41.2	19.6	11.8
Q-48: REVIEWS PRIOR TO EXAMS					
pretest	2.0	10.0	28.0	40.0	20.0
posttest	0.0	1.9	19.2	28.8	50.0

APPENDIX G: GENERAL COURSE MATERIALS

Appendix G contains some retyped copies of the general course handouts given to students during the course. Instructor names have been removed and spacing has been slightly changed on several handouts so that they would fit on a dissertation appendix page. Most handouts were given near the beginning of the course. The handouts are provided so that ethnographically one might be able to understand the course mileau to some degree, the instructions the students received and perhaps some insight into the impressions that students formed from reading them.

GENERAL COURSE MATERIALS LISTING

Course description: Spring 1985	Page 274
Course Schedule: Spring 1985	Page 275
Summer 1985	Page 279
Course Statement: Spring & Summer 1985	Page 276
Laboratory Notebooks: Spring & Summer 1985	Page 277
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Laboratory Term-end Feedback: Spring & Summer 1985	Page 278

PHYSICAL SCIENCE 203 SPRING 1985

Lecture: Dr. K... C..... 130 N. Kedzie Lab. 353-9271

Laboratory Instructors: J.... O.... 113 N. Kedzie Lab. 355-7565
T.. T..... 113 N. Kedzie Lab. 355-7565

(Messages may be left at Department Office: 355-4600)

Office Hours: C..... Monday 2:00 - 3:00; Tuesday 8:00a.m.-9:00a.m.; & by Appt.
O.... Monday & Wednesday: 4:00 - 5:00 p.m. & by Appt.
T..... Tuesday & Thursday: 12:00 M - 1:00 p.m. & by Appt.

Text: Conceptual Physics, Paul Hewitt (4th Edition), Required.
Laboratory Manual: Purchase at Kinko's Copying Service, 108 Divison,E.L.Required.

LECTURES: Mon.,Wed.,Fri., 3:00 p.m. 105 SKH for all sections
LABORATORY: Section 1 - - Tuesday 7:00 p.m. 110 N.K.L.
Section 2 - - Tuesday 10:20 a.m. 110 N.K.L.
Section 3 - - Tuesday 3:00 p.m. 110 N.K.L.

RECITATION: Section 1 - - Thursday 7:00 p.m. 110 N.K.L.
Section 2 - - Thursday 10:20 a.m. 110 N.K.L.
Section 3 - - Thursday 3:00 p.m. 110 N.K.L.

You are expected to attend all scheduled classes. If you must miss your scheduled Lab. or Recitation session, you may attend another section session during the week. Try to let your Laboratory Instructor know in advance. Since many of the Lab activities require elaborate equipment set-ups, it will proabably not be possible to make up Lab. work after Tuesday. If you must miss an EXAM, please let us know in advance so that alternate activities may be arranged.

Course Grades will be assigned on a point system, according to the following:

TYPE OF WORK	POINTS POSSIBLE	
LABORATORY - Write-ups due during Recitation each week	10 x 10 points	100
PROBLEM SETS - Due during Recitation as scheduled	5 x 10 points	50
DATA-GATHTERING - Pre-test (if any), Post-test, etc.	10 points	10
LECTURE-LAB QUIZZES - Given during Lecture, some may be unannounced	5 x 8 points	40
UNIT (HOUR) EXAMS - Given during lecture as scheduled	4 x 50 points	200
TERM FINAL EXAM - Given 12:45 - 2 :45, Friday, 7 June	100 points	100
TOTAL POSSIBLE:		500

Final grade for the course will be assigned based on the following points totals:

COURSE GRADE	Minimum points
4.0	460
3.5	440
3.0	420
2.5	400
2.0	380
1.5	360
1.0	340

(Extra-Credit opportunities may be available--Check with Instructor)

PHYSICAL SCIENCE 203, Spring '85, Schedule

DATE	LECTURE	READINGS	PROBLEM SETS	LAB & RECITATION ACTIVITIES
27 Mar.	Science	Ch. 1	None	Obtain Lab Manual, Do pre-Lab # 1
29 Mar.	Waves	Ch. 17	Handout	METRIC Measurement
1 Apr.	Waves	"		
				Tu. Metric Measure, Waves
3 Apr.	Sound	Ch. 18		
				Th. Discussion
5 Apr.	Sound	"		
8 Apr.	Sound	Ch. 19		
				Tu. Waves & Sound
10 Apr.	Sound	"		
				Th. Review #1, Problem Set
12 Apr.	EXAM #1		Handout	
15 Apr.	Light	Ch. 26		
				Tu. Pinhole Camera, Shadows
17 Apr.	Light	Ch. 28		
				Th. Discuss Lab., Exam
19 Apr.	Color	Ch. 29		
22 Apr.	Color	Ch. 27		
				Tu. Lenses, Color
24 Apr.	Color	Text.Backcover		
				Th. Review #2, Problem Set
26 Apr.	EXAM #2		Handout	
29 Apr.	Heat	Ch 14.		
				Tu. Heat Measurement
1 May	Temp.	Ch. 15		
				Th. Discuss Lab., Exam
3 May	Heat	"		
6 May	Temp.	Ch. 16		
				Tu. Heat, Energy, Power, Review
8 May	EXAM #s3		Handout	
				Th. Electric Circuits #1
10 May	Elec.	Ch. 20		
13 May	Elec.	Ch. 21		
				Tu. Electric Circuits #2
15 May	Elec	"		
				Th. Discuss Lab., Exam, Problems
17 May	Magnets	Ch. 23		
20 May	El. & Mag.	"		
				Tu. Electromagnets
22 May	"	Ch. 24		
				Th. Review #4
24 May	EXAM #4		Handout	
27 May	Holiday			
				Tu. Simple Machines
29 May	Machines	Ch. 8		
				Th. Discuss Exam, Problems
31 May	Work, Energy	Ch. 9		
7 June	Term Final Exam, 12:45 p.m.			(review sessions during Exam Week)

Refer to syllabus, Course Statement, or instructors for more information.

PHYSICAL SCIENCE 203

COURSE STATEMENT

1. Course philosophy & content

The need for scientific literacy is increasing in our society, but the number of Ameri- cans with only the rudimentary notions of science portends trouble in the decades ahead. Jefferson's axiom that an enlightened citizenry is the only safe repository of control over the ultimate processes of society surely includes the necessity for scientific enlightenment today. This situation has many troubling implications and unless the current trend toward scientific illiteracy is reversed, important national decisions will be made increasingly on the basis of ignorance and misunderstanding. Our educational system must provide a greater understanding to the "non-scientist" and "scientist".

This course is designed to help you improve your understanding, appreciation, and enjoyment of physical science. In the short time available in a 10-week course, we will concentrate only on six major areas: 1) measurement. 2) sound & waves, 3)light & color, 4)electricity & magnetism, 5) heat and temperature, and 6) energy & machines. A working knowledge of these six areas should provide you with sufficiaent breadth to successfully work with children in most areas of physical science, and a framework from which to expand your horizons.

2. Course structure

The course is divided into four activities: three hours of lecture each week, two hours of inquiry lab each week, one hour of recitation each week. Where practical, we have attempted to coordinate lecture-recitation and lab materials.

Lecture

The lectures will focus on developing a number of fundamental physical concepts through a wide variety of simple, yet effective demonstrations. Many of these demonstrations can be used with little or no modification in the elementary school classroom. The lectures should complement well our concept-oriented textbook. (Keep it for future use.)

Inquiry Labs

The laboratory is designed to give the student a guided-discovery, hands-on experience. It is devoted to those topics which are greatly enhanced by student-student and student-instructor dialogue. As the name implies, the process of inquiry cannot be the burden of the instructor alone. It will be successful to the extent that there is a functional and meaningful dialogue among the class members. Reading your labs and doing your pre-labs before class is of utmost importance for a satisfying experience. During the lab period, the instructor might answer your question with a question. Don't be surprised! He/she is not being rude, but is using a guided-discovery approach. After each lab, you are expected to spend time at "home" writing your insights in your lab notebook, which will be turned in to your lab instructor.

Recitation

These discussions sessions will serve to clarify and expand (often more in depth) the ideas presented in lecture and lab. This is when your lab notebooks will be given to your lab instructor. There will also be time for reviewing for tests, going over tests, and some student projects. Current "events" and other timely discussions can occur.

The course is structured in "two week" units with advance organizers. It emphasizes individual achievement, provides alternative instructional approaches simultaneously, and allows the instructors to serve as models for teaching science. An exam follows each unit and is explained the following week. There is a final exam which covers all the units. The grading is not on a normal curve, but is criterion based. (see syllabus) We hope you enjoy the course as much as we do teaching it. Always feel free to contact us.

Laboratory Notebooks

Obtain a separate notebook just for laboratory activities. It may be a spiral notebook or pouched folder. Paper size should be 8 1/2 x 11. Keep all your pre-labs, lab write-ups and other lab exercises together in your notebooks. Ask your lab instructor for clarification. There are several reasons for your lab notebook.

First, we will require some written insight, explanations, and analysis for each laboratory. This is in compliance with MSU emphasis on developing reading and writing skills in every class. Recent research has indicated that most American students cannot write a coherent analysis of what they read. Most of their written explanations and opinions are superficial and limited at the expense of reasoned and disciplined thought. Most students seem satisfied with their initial interpretations and genuinely puzzled at requestsd to explain or defend their points of view. Of the more than 106,000 students who were evaluated, only 5 to 10% showed strong analytic skills, while about 15% showed no evidence of being able to analytic tasks at all. Classroom teachers who drill students to give only quick, easy answers and opinions may be to blame.

Secondly, it can provide space, if necessary for taking lab notes, making calculations, data, etc. However, in most cases you will want to do this directly on your lab exercises. Thirdly, finding and commenting on current scientific articles and ideas may be included in your notebook. Fourthly, your notebook may serve as an excellent record of your lab experience.

Each week, your lab instructor will indicate what specifics will be required. Coming to lab with your pre-lab complete, you should be able to make all the necessary observations during the lab period. After lab, you are expected to reflect on 1the experience and write usually form two to four pages in your notebook. Use complete sentences and para-graphs. Write so that we can read it easily. Your notebook is due the following recitation. Suggestions for lab improvement will always be acceptable. Where possible, give page number, state the problem and recommend a change.

LABORATORY GRADES

In general, since the lab approach is guided-discovery, a certain number of "right" answers is not the primary criterion for grades. Certainly clear thinking is important, but doing competent lab work does not always produce the "right" answer. In addition to your insights and conclusions in your lab notebook write-up, the lab instructor will be evaluating your pre-labs (partial evidence of reading the exercise before lab), your ability to read and follow directions and procedures during lab period (partial evidence of prior reading), and your ability to work together well during lab period (partial evidence of prior reading). This interaction among pre-labs, use of lab time, and lab write-ups will be reflected in your grade for each lab. Be sure you ask your lab instructor when you have questions.

PLEASE RATE THE FOLLOWING ITEMS.
LABS: CONSIDER HOW THE HANDS-ON, CONCRETE EXPERIENCES & SMALL GROUPS HELPED YOU IN UNDERSTANDING COURSE CONCEPTS.
FOR PROSPECTIVE TEACHERS: CONSIDER ALSO EACH TIME AS A POTENTIAL RESOURCE FOR YOUR TEACHING KNOWLEDGE.

1	2	3	4	5
EXTREMELY HELPFUL	VERY HELPFUL	SOMEWHAT HELPFUL	SLIGHTLY HELPFUL	NOT HELPFUL

26. METRIC MEASUREMENTS: prefixes related to money, making estimates then measurements, using length, area, volume, mass, weight. "Metric Me".

27. WAVES & SOUND: making sketches, using slinkies, ripple tanks, resonance tubes and tuning forks to measure the speed of sound

28. PINHOLE CAMERA: construction, exposure, developing negative and print, related images to eye.

29. SHADOWS & COLOR SHADOWS: making shadow shapes, seeing light rays, mixing colors, using cones.

30. LENSES: image predictions and projections. human eye: near and far-sightedness.

31. ELECTRICITY: predicting and testing: open and closed circuits, series and parallel circuits, ohm's law, football stadium analogy.

32. HEAT: measuring heat and temperature, heat capacity, radiation cans, using food coloring for kinetic energy, convection currents, "mystery" metal.

33. SIMPLE MACHINES: conservation of energy, levers, ramps, pulleys, mechanical advantage, trade force for distance, everyday examples.

1 2 3 4 5

34. THE SYSTEMATIC RELATIONSHIP BETWEEN LAB ACTIVITIES AND UNIT TOPICS?

35. THE LAB INSTRUCTOR'S CONCERN WITH WHETHER THE STUDENTS LEARNED THE MATERIAL?

36. THE LAB INSTRUCTOR'S ASSISTANCE IN HELPING YOU UNDERSTAND AND REVIEW CONCEPTS?

37. THE STUDENT'S OPPORTUNITY TO ASK QUESTIONS DURING AND AFTER LAB?

38. IMPROVEMENT IN YOUR APPRECIATION OF SCIENCE AND HOW IT RELATES TO EVERDAY EXPERIENCES?

PLEASE INCLUDE WRITTEN COMMENTS ON THE BACK OF THE EVALUATION FORM. THANK YOU.

PHS 203 SUMMER SCHEDULE 1985

DATE	LECTURE	READINGS	SUGGESTED EXERCISES	LABORATORY & RECITATION PERIODS
W 6/19	Science	Ch. 1	None	METRIC MEASUREMENT
Th 6/20	Sound	Ch. 17	Rq. all Ex. all even	questionnaires & projects
F 6/21	Sound	Ch. 18	Rq. all Ex. all exc. 8,10,14	NONE
M 6/24	Sound	Ch. 19	Rq. 1,2,12 Ex. 1,6,8,12,20	SOUND & WAVES
Tu 6/25	Sound			review--sound
W 6/26	TEST #1			PINHOLE CAMERA
Th 6/27	Light & Color	Ch., 26 (410-17)	Rq. 1-5 Ex. 1-6	Discuss TEST #1, SHADOWS lenses handout
F 6/28	"	Ch. 28	Rq. 4, 8-15, Ex.10,11,15 24,28,33	NONE
M 7/1	Light & Color	Ch. 29	Rq. 1-5 Ex. 2-4,8,12-20	LENSES
Tu 7/2	"	Ch. 27	Rq. all Ex. all	COLOR & COLOR SHADOWS
W 7/3	Light & Color	back-cover	color problems handout	review - light & color
Th 7/4	---------------NO CLASS--------------HOLIDAY----------------------------------			
F 7/5	TEST #2			NONE
M 7/8	Elec. & Mag.	Ch. 20	Rq. 1,2,4,7-12,15 Ex. 1-7,12-14	ELECTRIC CIRCUITS
Tu 7/9	"	Ch. 21	Rq. all Ex. 9-16,19,23,24	Discuss test #2
W 7/10	"	Ch. 23	Rq. 2,4,6,10,11 Ex. 2,10-12	ELECTROMAGNETS
Th 7/11	"	Ch. 24	Rq. 2, 4-8,10 Ex. 7-8	review--electricity
F 7/12	TEST #3			NONE
M 7/15	Heat & Temp.	Ch. 14	Rq. all Ex. all	HEAT MEASUREMENTS
Tu 7/16	"	Ch. 15	Rq. all Ex. all odds	Discuss TEST #3
W 7/17	"	Ch. 16	Rq. all Ex. all odds	HEAT MEASUREMENTS
Th 7/18	"	Ch. 16	" " "	SIMPLE MACHINES
F 7/19	ENERGY	Ch. 8	Rq. 1-10 Ex. 5,9,23,27,28	NONE
M 7/22	"		Energy practice sheets	SIMPLE MACHINES
Tu 7/23	POWER	Ch. 9 epilogue	Rq. all Ex. all	Review--heat,energy, power
W 7/24	TEST #4			NONE
	FINAL____			

NOTE: REFER TO SYLLABUS, COURSE STATEMENT, AND INSTRUCTORS FOR MORE INFORMATION.
*Under suggested exercises, the Rq = review questions and the Ex = exercise are the questions at the end of the chapters in your textbook.

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