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Inservice workshop for high school physics teachers: An evaluation

Carroll, Terry Neal, Ed.D.

The University of North Carolina at Greensboro, 1989

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INSERVICE WORKSHOP FOR HIGH SCHOOL PHYSICS TEACHERS: AN EVALUATION

by

Terry N. Carroll

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

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Approved by

Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

Dissertation Adviser

Committee Members

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CARROLL, TERRY NEAL, Ed. D. Inservice Workshop for High School Physics Teachers: An Evaluation. (1989) Directed by Dr. Ernest W. Lee. 154 pp.

The primary purpose of this study was to determine the short-term and long-term changes in content knowledge of physics teachers who participated in a 5-day inservice workshop.

The study examined the relationships between participants' content knowledge changes and physics teaching experience, formal academic preparation, and materials development and teaching. The study also compared participants' performance on conceptual questions and analytical problems.

The subjects consisted of 22 high school physics teachers who participated in an inquiry inservice workshop held at North Carolina State University in 1988.

Analysis of the data consisted of comparisons between the pretest scores and both the short-term and long-term posttest scores to determine content knowledge changes in each of the physics topic areas studied. To test for statistical significance between pretest and posttests, a one-tailed dependent _t_ test was used.

The primary experimental treatment was participant involvement with inquiry instructional materials and strategies in five 2-hour "minilessons". A secondary treatment was development of additional instructional materials in one of the areas studied. A test battery of five written content tests in physics were at the introductory precalculus college level and represented a wide range of difficulty.

The analysis of data revealed the following general trends: 1) There was a significant short-term increase in mean scores, but there was no significant long-term increase. 2) Materials development and teaching did not increase short-term or long-term content knowledge scores significantly. 3) The level of academic preparation in physics was a factor in initial performance, but there was no significant retention over a 3-month period for any of the groups. 4) Years of experience in teaching physics was a factor in initial performance with the more experienced teachers generally scoring higher than the less experienced teachers. 5) Participants had a significantly larger percentage of correct responses on the conceptual questions than on the analytical problems.

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CHAPTER I

At a time when our society is becoming more and more technologically complex, we are having to become increasingly aware of the educational problems which face us in many areas including the area of science education. Neuschatz and Covalt (1988) have stated that a well-trained and scientifically literate population is needed to ensure the future economic competitiveness and socio-political health of our society. Routinely, citizens find themselves facing decisions that require scientific judgements, however, many are poorly equipped to make such judgements on a scientifically literate basis. Bloom and Rabinowitz (1985) have pointed out that many state and national studies have identified secondary science instruction as inadequate due not only to the poor performance by students in science, but also to the knowledge explosion and emerging technology.

One of the areas in science that has the greatest need for improvement is high school physics instruction. The American Association of Physics Teachers (AAPT) (1988) stated:

> Many more students should study physics in high school. Our society is technologically based and would benefit greatly if more of its citizens

> comprehended the principles of physics. Informed voting on such issues as energy policy, protection of the environment, safety of nuclear plants, and disposal of nuclear wastes is aided by an understanding of basic physics. Strengthening the economy, preparing for technological change, and meeting economic competition from abroad also demand a better educated work force: more and better physics education is one important part. (p. 105)

Although more attention has been focused on this problem recently, it is not a new problem. Rakow (1986) observed that in response to the launch of the Soviet satellite, Sputnik, the federal government of the United States appropriated large sums of money to upgrade the teaching of science and mathematics.

Inquiry instruction, which includes the hands-on manipulation of materials, was a common element in all of the "new" science curriculum projects. The laboratory was the center of attention and the various new curriculum projects such as the Physical Science Study Committee (PSSC) emphasized and provided opportunities where students themselves were investigators (Trowbridge, Bybee, & Sund, 1981). This "new" approach marked a shift from teaching science as a fixed body of facts to be memorized toward learning science through the affective processes of inquiry and discovery (Bybee, 1974). Harms and Yager (1981) suggested that inquiry instruction utilizes a variety of methods such as discussions, investigative laboratories, student-initiated inquiries, lectures, and debates.

According to Sund and Trowbridge (1973) millions of dollars have gone into developing science materials more relevant to what is known about how students learn. Yet evidence suggests that innovative materials which stress inquiry have been adopted by many science teachers, but inquiry instruction is still not practiced in most science classrooms (Klopfer, 1980). Welch and others made the same observation, noting that "although teachers made positive statements about the value of inquiry, they often felt more responsibility for teaching facts, things which show up on tests, and structure of the work ethic" (Sweitzer, 1982, p. 5). After observing 1,100 classrooms, Brandwein arrived at the following conclusions:

> I found the words inquiry and process . . . being espoused all over the land, but let me give you my data: 90 percent of the teachers in the eleventh and twelfth grades lectured 90 percent of the time; 80 percent of the teachers in the tenth and eleventh grades lectured 80 percent of the time. They were all teaching through "inquiry." We defrauded ourselves . . . by using new words. (Cited by El-Gosbi, 1982, p. 11)

If the inquiry approach is to become an effective means of teaching, then teacher-training institutions must reexamine their training practices. Future teachers must have the opportunity to learn and practice the process of inquiry instruction. McKinnon and Renner (1971) have observed that those who are teaching have been educated in existing colleges and universities where they have been lectured to, told to verify, given answers, and told how to teach. These new teachers, therefore, assume that telling is teaching. Whitaker and Renner (1974) gathered data which suggests several important priorities held by instructors who teach introductory college physics. The investigators concluded that many instructors of introductory physics courses do the following:

(a) believe that student mastery of the content of physics is the most important objective in the course in which they teach;

(b) believe that student mastery of the content of physics is the most important objective in the individual class periods;

(c) believe that other objectives, particularly those dealing with the broader, cultural aspects of physics, to be of minimal importance;

(d) employ lecturing and problem solution by the instructor, but mostly lecturing, as their primary teaching methods;

> (e) ask questions in such a way that a single response is expected or that the instructor himself answers the questions, i.e., primarily convergent or rhetorical questions;
>
> (f) ask questions which are the least intellectually demanding of the student, i.e., primarily knowledge and comprehension questions which require mainly recall to answer;
>
> (g) place primary importance upon written materials through reading the textbook or working problems with minimum use of demonstrations or references to the student laboratory. (p. 827)

Riley (1979) noted that the literature expresses a need for teacher proficiency in science process skills and involvement in hands-on science experiences. There is a belief that improving a teacher's understanding of and attitude toward science would increase and improve science instruction.

Lombard (1982) noted that the importance of physical action to concept formation was tested by Wollman and Lawson. One group of secondary students was exposed to the traditional instruction while another group was exposed to physical materials and a variety of problem-solving techniques. The latter group was superior in the development of concept formation after the instruction and remained so at the time of a posttest one month later.

Schneider and Renner (Lombard, 1982) found that in physical science classes concrete operational students made more gains in content achievement when exposed to inquiry methods of teaching.

Much of the physics education problem stems from having insufficient numbers of qualified physics teachers teaching high school physics and physical science courses. Franz, Aldridge, and Clark (1983) suggested that the crisis in physics education has two primary components: the severe shortage of qualified physics teachers and the small fraction of high-school students choosing to take physics. According to a 1981 survey by the Association for School, College, and University Staffing, 42 of the 45 states responding reported shortages of physics teachers (Hirsch, 1984). In a survey of the 326 high school physics teachers in North Carolina (Johnston, 1987), of the 40% who returned their survey, 64% had not taken a calculus-based physics course, and only 13 had a major or minor in physics. One of the major findings of an investigation by Howe and Gerlovich (1981) is that there are critical shortages of teachers in the areas of mathematics, general science, earth science, physics, and chemistry. Their research suggests that many math and science courses are being taught by less qualified teachers with minimal or no preparation in math and science. Teacher shortages may cause many schools to drop some mathematics and science offerings.

In a recent report by the American Institute of Physics (AIP), of the 3,301 physics teachers surveyed nationwide, 2,485 completed AIP's 12-page questionnaire. Of these, only about one fourth had earned a degree in physics. This is particularly alarming when one considers that the key factor in determining the quality of instruction is the teacher (Neuschatz & Covalt, 1988). Again as stated by AAPT (1988):

> Excellence in high school physics depends on many things: The teacher, course content, availability of apparatus and time for laboratory experiments, a clear philosophy and workable plan for meeting students' needs, serious dedication to learning goals, and adequate financial support. The role of the teacher, however, is the most important. Without a well-educated, strongly motivated, skilled, well-supported teacher, the arch of excellence in high school physics collapses. The teacher is the keystone of quality. (p. 105)

Improving instruction through inservice workshops is one of the few and immediate solutions in a climate of an aging faculty, inadequately prepared teachers, the knowledge and technological explosion, and the trend toward more rigor and excellence (Bloom & Rabinowitz, 1985).

<u>Educating Americans for the 21st Century</u> (National Science Board Commission, 1983) recommends a combination of programs where the federal and individual state governments, in cooperation with colleges and universities, provide upgrading for teachers. This would be accomplished by developing teacher training programs in mathematics, science, and technology to provide for academic-year and summer inservice institutes.

While hard evidence of the effectiveness of inservice is generally lacking, a few studies have shown that inservice activities can change teacher behavior and increase student learning (Kane & Chase, 1983). A study by George and Nelson (1971) suggested that not all of the teachers benefited from being involved in the inservice work. The study also suggested that age and experience may be factors in ability to teach science as inquiry. While it is generally believed that most workshops are beneficial, due to limited resources and time it is important to determine what works best with which groups of physics teachers.

It has been calculated that in fiscal year 1980 approximately 340 million dollars was spent at the federal level alone on inservice training, and there is evidence that the United States at the federal, state, and local levels combined may be investing almost 3 billion dollars a year for inservice education. From a fiscal perspective, inservice teacher education is obviously a major activity in America's public schools (Spector, 1987). Miller (1978) believes that while expenditures will remain basically the same, today and in the future high-quality education programs will be required and expected by our more highly educated and articulate citizenry. One of the possible implications of this is that inservice experiences will be assessed, and one-shot entertainment-type inservice sessions will be eliminated. The demand for more appropriate and effective inservice will grow and much more use will be made of educational technology.

A review of the literature has indicated that many of the studies conducted on the effectiveness of inservice have investigated questions in the affective domain with broad groups of teachers (e.g., elementary or middle-school science) frequently using questionnaires as the primary evaluation instrument. In a meta-analysis of research between 1965 and 1980 on preservice and inservice inquiry practice, Sweitzer (1982) found only 7 of the 97 studies analyzed the evaluated content knowledge of the participants. Nevertheless, he believes that content knowledge will be evaluated more frequently in future inservice workshops.

The diversity of teachers' backgrounds is one of the factors which must be considered in designing inservice education. Within the profession science teachers have a variety of academic credentials and needs. There are (a) those with current degrees in science education who are high performing and want to continue studying, (b) those with degrees in science education from many years ago who need updating, (c) those with degrees in science who need certification to teach science, and (d) those with undergraduate non-science degrees who require certification and need a stronger base. Teachers in the last category constitute a major new audience for inservice teacher education (Spector, 1987).

While various inservice models are being used to upgrade science teachers' content knowledge, methods, and teaching skills, this study was concerned with the evaluation of one model: the "Teaching Physics Teachers with Technology" (TPTT) inservice workshop. TPTT was a modified version of its predecessor, the "Chautauqua" type of inservice workshop and was based on the successes and recommendations for improvement from the Chautauqua workshops. Since many physics teachers feel they lack models, support materials, and content knowledge, the purpose of the TPTT workshop was to increase the content knowledge of the participants by demonstrating good physics teaching inquiry models, using various classroom technologies and having the participants develop classroom materials utilizing various classroom technologies. The workshop has been funded by the National Science Foundation for 3 years and was designed to serve 25 North Carolina physics teachers each year. The 75 teachers who will complete this workshop represent approximately 25% of the state's high school physics teacher population.

The workshop concentrated on the use of computers in physics instruction, using a variety of strategies in topic areas in which many physics teachers felt uncomfortable teaching. The workshop integrated demonstration, laboratory activities and other instructional modes into the inservice program.

The primary purpose of this study was to determine the gain in physics content knowledge of high school physics teachers who participated in the "Teaching Physics Teachers with Technology" workshop. The study would determine whether inquiry instruction is sufficient to produce gains in content knowledge, would identify the workshop strengths and weaknesses, and would identify target groups of high school physics teachers and the type of instruction they most need and benefit from.

The participants' performance gain on content knowledge was measured by a series of three test batteries composed of written tests in each of five topic areas: (a) mechanics, (b) optics, (c) thermodynamics (thermal), (d) electricity and magnetism (E&M), and (e) modern physics (modern). These tests represent a wide spectrum in level of difficulty but are all at the introductory precalculus college level.

Another aspect of the study was to examine the retention of content knowledge over a 3-month period. An examination was also made of the relationship between physics content knowledge learned by those teachers only participating in minilessons and those who taught the content materials before the final meeting of the workshop participants in the fall.

This investigation serves as a pilot study to focus on the ability of inquiry instruction to teach content knowledge which can be measured by the standardized test type of questions. This is an important concern which must be addressed as we shift from the traditional lecture method of teaching content to the various inquiry-discovery methods. The treatment in this study was the participant involvement in minilessons, materials development, and teaching content knowledge via various inquiry methods.

The study was difficult in part because the number of teachers teaching physics in North Carolina is only slightly more than 300. It is estimated that only about 10% of those have either a major or minor in physics (Johnson, 1987) and approximately half of those with a physics major or minor are attending the first TPTT workshop, making it virtually impossible to have an equivalent control group. A second problem with conducting content knowledge research for this group is the lack of content-specific standardized tests with predetermined validity ratings.

Purposes of This Study

The primary objective of this study was to determine to what extent inquiry instruction improved content test scores among a group of 22 North Carolina high school physics teachers. The investigations in this study were conducted for the following reasons:

1. To determine the content knowledge performance of TPTT participants in each of five physics topic areas on a written pretest based on the minilesson objectives.
2. To determine and compare the short-term content knowledge performance gains in the five topic areas as a result of the minilessons by comparing the pretest results with the performance on a written posttest given at the conclusion of the summer workshop.
3. To determine the long-term content knowledge gains of the participants as a result of the summer workshop by comparing the pretest results with the performance on a written posttest given during the fall workshop.
4. To determine the content knowledge gains in the topic areas in which the participants developed and taught materials with objectives similar to the objectives of the minilessons.

5. To determine the relationship of formal physics education to content knowledge gains.
6. To determine the relationship of number of years of experience teaching physics to content knowledge gains.
7. To compare the performance of participants on conceptual questions and analytical problems on the three test batteries.

This study will contribute to learning about integrating content and inquiry and what to expect from and how to best serve various subgroups of high school physics teachers.

Basic Assumptions and Limitations

Assumptions

1. It was assumed that data regarding participants' experience and academic background were accurately reported.
2. It was assumed that the evaluation instrument was accurate in measuring content knowledge for this study.
3. It was assumed that the participants made a consistent effort to solve or answer each problem or question on the evaluation instruments.

Limitations

1. The study was limited to a self-selected group of 22 high school physics teachers who participated in the Teaching Physics Teachers with Technology workshop during the spring, summer, and fall of 1988.

2. The study was limited to the five content knowledge areas in physics that were examined.
3. The study was limited to the performance of the participants on the tests given during three test sessions.

Definitions and Explanations

1. Chautauqua-type program: A 3-year NSTA/NSF Precollege Science Teachers inservice program where an "expert" delivers a two-day workshop on a particular physics topic. During an interim period participants develop classroom materials and then return for a follow-up two-day workshop.
2. "Teaching Physics Teachers with Technology" (TPTT): A 3-year NSF grant with the Department of Physics at N.C. State University similar to the Chautauqua-type program. The TPTT inservice for 25 high school physics teachers consists of a 2-day technology introduction workshop in the spring followed by a 5-day workshop in midsummer followed by a 2-day follow-up and evaluation session in the fall. The summer 5-day session is time given to group instruction with examples of various technologies and teaching strategies in five topic areas of physics. The instruction is followed by small-group materials development for sharing and field

testing with the participants' physics classes in the fall.

3. Content Knowledge Performance: A measure of the number of questions/problems correctly completed on pre/posttests based on the teaching objectives of the five physics minilessons taught during the summer 5-day TPTT workshop.

4. Minilessons: Two-hour hands-on inquiry lessons using various classroom technologies in physics content areas (e.g., capacitance, refraction, radioactivity, thermal properties, circular motion) which have received less attention than many other areas of physics.

5. Materials development: The TPTT workshop participants were divided into five groups to utilize classroom technologies and a variety of teaching strategies other than lecture to develop "Physics Teaching Modules" (PTM) for field testing in their own physics classes in the fall. Teachers were encouraged to use new technologies in their teaching and to move away from teaching physics primarily by lecture. Teaching of the modules required approximately two or three class periods and used many different resources such as computer-based lessons, video, audio, laboratory and demonstration activities. The modules are suitable for use in one- or multiple-computer classrooms.

Organization of This Study

Data for this study was obtained during the summer and fall of 1988. A group of 22 North Carolina high school physics teachers who participated in the TPTT workshop were involved in the study. The entire group of teachers was involved with all five of the 2-hour minilessons and with materials development in one of the five topic areas. After participants developed their materials, they "field tested" them before the fall 2-day follow-up workshop.

To investigate the various hypotheses, the following experimental designs were employed: (a) a one-group nondesign with a correlation study and (b) a quasi-experimental untreated control group design. Both experimental designs utilized a pretest (Test Battery I), short-term posttest (Test Battery II), and long-term posttest (Test Battery III).

The one-group design and the correlation studies were useful in investigating the hypotheses (1, 2, 4, 5, 6, 7, 8) concerning the whole group (i.e., initial results and how various groups of participants with different levels of physics academic preparation did on Tests I, II, and III). The one-group design was necessary because the number of high school physics teachers statewide is small.

The quasi-experimental untreated control group design was used to investigate the hypothesis (3) concerning the topic areas where part of the group received a treatment in that particular topic area while the remainder of the group did not receive that treatment (i.e., those participants who developed PTM with objectives similar to those of the respective minilessons). Since the participants were chosen instead of selected at random for the workshop, the design for this part had to be quasi-experimental.

The evaluation for this study consisted of a pretest (Test Battery I) at the beginning of the summer 5-day workshop, a short-term posttest (Test Battery II) at the end of the summer workshop, as well as a long-term posttest (Test Battery III) 3 months later during the fall 2-day workshop.

Analysis of the data consisted of comparisons between the pretest and both the short-term and long-term posttest scores to determine content knowledge gains in each of the physics topic areas studied. To test for statistical significance between pretest and posttests, a one-tailed dependent _t_ test was used (Best, 1981). Because the sample size was small in most of the comparisons, rather than using the normal probability table, the _t_ table Student's Distribution developed by William Sealy Gosset was used to determine statistical significance (Best, 1981). The dependent _t_ test used required the use of the Pearson Product-Moment Correlation Coefficient in its calculation. While these values are not given, the values generally ranged from .60 to .90 between various sets of pre- and posttests.

Study Overview

This chapter provides an introduction and background information related to the problem under study as well as the purposes, basic assumptions, limitations, definitions, and organization of the study. Chapter II is a review of the literature which includes research in the areas of need for better physics education, teacher profiles of those presently teaching secondary physics, science preservice, classroom materials and technologies, inquiry teaching, science inservice, and other topics. Chapter III is a detailed discussion of the hypotheses, the experimental design, the sample description, the experimental treatment, the research instruments, and data collection and analysis procedures. Chapter IV presents the analysis of the data and the results of the study. Chapter V includes a discussion of the findings, observations and conclusions, implications of the study, and recommendations for future study.

CHAPTER II

REVIEW OF THE LITERATURE

Importance of Physics Education

> The Nation that dramatically and boldly led the world into the age of technology is failing to provide its own children with the intellectual tools needed for the 21st century. . . . The world is changing fast. Technological know-how is spreading throughout the world - along with the knowledge that such skills and sophistication are the basic capital of tomorrow's society. . . . We must return to basics, but the "basics" of the 21st century are not only reading, writing and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy - the thinking tools that allow us to understand the technological world around us. (NSF, 1983, p. v)

Scientific knowledge is increasing at an exponential rate. It is estimated that the total quantity of knowledge in any given field of science more than doubles every ten years (Trowbridge, Bybee, & Sund, 1981).

Harms has suggested that as a society, we are becoming more aware of the limitations of our natural resources. The result is that the general public is taking more interest in scientific and technological issues and is actively participating in societal decisions on many science and technology related issues (Harms & Yager, 1981). This requires citizens to understand the scientific aspects of these important societal issues.

Twenty years ago, most science educators believed the achievement of technological supremacy was seen by many as an important national goal and that "the good life" depended on technological progress (Harms & Yager, 1981). Trowbridge, Bybee, and Sund (1981) believe all members of society should be aware of the relationships between science, technology, and society in order to better assess the potential and the limitations of science and technology for resolving (or creating) some of our most serious problems. Today's renewed focus on improving science instruction is in part fueled by both a concern that we maintain a large number of scientists and the need for all citizens to be scientifically literate in this increasingly technological society (Guthrie, 1985). Newt Gingrich, a member of U.S. House of Representatives, stated:

> First of all, science education from a public policy standpoint is important. It's important economically. We need more scientists and engineers. In the age of DNA and the computer, basic science knowledge is as important as basic internal combustion and mechanical engineering was in the age of steam. We have not

> really integrated that into our thinking about what it means to be economically useful in the 21st century. To understand public policy issues, science and the scientific approach are increasingly important. Whether you are trying to understand Three Mile Island, trying to understand whether we should go toward nuclear power, trying to understand the risk factors in, for example, the spread of AIDS - in every one of those cases understanding the scientific method and the framework of asking intelligent questions are important for every adult citizen. Scientific illiteracy is a threat to the very survival of our free society. (Champagne & Hornig, 1986, pp. 22-23)

Layman (1983) wrote that science and mathematics education in this country has deteriorated to the point of becoming a crisis. This is confirmed by a number of editorials, the amount of legislation being proposed, and the attention given the subject by the press. Spector (1987) reported that "fourteen-year-old American students ranked 15th out of students from 19 countries in overall science knowledge. Only 16% of the nation's high school students took a chemistry course" (p. 7).

High School Physics Teacher Profile

One of the primary features in the crisis in physics education is a severe shortage of qualified teachers (Franz, Aldridge, & Clark, 1983). Harms and Yager (1981) point out that since the teacher makes most of the important decisions about course content, text selection, and instructional methods, the teacher is the key to effective science instruction. They believe good science instruction takes place when teachers are motivated, well-trained, and enthusiastic. The National Science Foundation-Department of Education report to President Carter stressed among other things that continuing education and retraining programs for primary and secondary school teachers needed to be strengthened (State University of New York, 1982).

> In terms of teacher supply and demand, the sequence of events began years ago. After World War II there was a baby boom. As these children came of school age, the need for more schools and teachers to staff them arose. However, by the 1970s there was a decline in the birth rate. This decline produced, eventually, an enrollment drop which hit the elementary schools and then the high schools. (Blosser, 1984, p. 245)

In the 1960s colleges and universities geared up to prepare more teachers, but by the early 1970s the popular press emphasized a "teacher surplus." This generalization failed to point out that "chronic shortages" persisted in certain selected and specialized fields. On a national basis, the teacher shortage in mathematics, and in natural and physical sciences continued (Blosser, 1984). Champagne and Hornig (1986) also warned that teacher vacancies do not accurately reflect shortages of science teachers due to the common practice of filling vacancies with whomever is available. Frequently, when vacancies occur in a science or math position, the present solution is to shift an underprepared teacher into that slot.

Data indicate that only one-third of the high school physics classes in the United States are taught by certified instructors trained in physics (Van Hise, 1986). In a recent report by the American Institute of Physics (AIP), of the 3,301 physics teachers surveyed nationwide, 2,485 completed AIP's 12-page questionnaire. Of these, only about one-fourth had earned a degree in physics (Neuschatz & Covalt, 1988). Layman (1983) pointed out that there are virtually no physics teachers in the pipeline. He stated that there are 65% fewer science teachers in training now than 10 years ago. In Iowa, for instance, 63% of those teaching physics do not have as much as a minor in physics. In 1981, a total of one physics teacher was graduated from all 12 state-supported colleges and universities in Minnesota (State University of New York, 1982). Lashier and Ryoo (1984) further defined part of the shortage problem as the high turnover rate among young qualified physics and chemistry teachers.

The decline in new science and mathematics teachers is matched by a corresponding rise in the number of unqualified teachers teaching these subjects. "In a recent National Science Teachers Association survey, 50.2% of the newly employed science and mathematics teachers were judged by their principals to be unqualified to teach in these fields but had been employed on an emergency basis" (Lashier & Ryoo, 1984, p. 17). Blosser (1984) discussed findings from a 1973-1978 survey in Missouri where there was a 16 percent shortage of science teachers. New York state, had a 50 percent decline in prospective physics teachers from 1975 to 1979, and it was anticipated this decline would continue. Hirsch (1984) reported that over the 3-year period from 1980 to 1983, the number of physics teachers in Michigan decreased by 10.9% from 265 to 236. Only one-third of the public senior high schools in Michigan had physics teachers with a physics major or minor and many high schools offered no physics or chemistry at all. Olstad and Beal (1981), describing a study done in Washington State from 1974 through 1978, found the following: (a) The number of vacancies in science and mathematics increased, (b) the number of majors and minors in science and mathematics recommended for a secondary certification decreased, and (c) the supply of science education majors was insufficient to meet the demand for full-time science teachers.

Preparation of High School Physics Teachers

> Physicists have become increasingly aware that if the scientific literacy of the general public is to be increased, education at the precollege level must be purposefully directed towards this goal. They have, furthermore, come to realize that physics departments in colleges and universities must share with schools and colleges of education the responsibility for insuring that this task is accomplished effectively. There is a vital need for physicists to take an active role in the training of teachers in physical science not only for secondary schools but for the elementary grades as well. (McDermott, 1974, p. 668)

Excellence in high school physics depends on many things: the teacher, course content, availability of apparatus, time for laboratory experiments, and adequate administrative and financial support. The teacher, however, is the most important of these. Without a skilled, well-educated, strongly motivated teacher, excellence in high school physics is not possible. Physics teachers first need an excellent background in physics content. This begins with undergraduate preparation in physics, mathematics, and related sciences with associated laboratory work, use of calculus, and use of computers. The undergraduate physics preparation should include an introductory physics course, as well as courses above the introductory level in mechanics, electricity and magnetism, modern physics, optics, and thermodynamics (AAPT, 1988). The National Science Teachers Association (NSTA) (1984) recommends that preservice high school science teacher preparation include coursework which (a) emphasizes science content, (b) increases skill in using the processes of science, (c) increases understanding of the relationship between science, technology, society, and human values, (d) enhances positive attitudes toward science, and (e) develops the prospective teacher's mastery of a broad range of laboratory and field skills. This preparation should require competency in computer applications to science teaching with emphasis on computers as tools for (a) computation, (b) interfacing, (c) processing information, and (d) testing and creating models.

McDermott (1974) described a preservice physics course at the University of Washington where future teachers acquaint themselves with the "new" high school curricula. All of the students have had 2 or 3 years of lecture and formal laboratory instruction, and since most people teach as they have been taught, this course attempts to teach the inquiry method by involving students in direct experiences with the teaching materials. Leonard (1969) also described the science methods course at San José State College where the prospective teacher practices with methods, materials, and procedures. A large part of the course requires lesson presentations by members of the class, followed by a critique and discussion of each presentation.

Whitaker and Renner (1974) revealed several important priorities held by introductory college physics instructors. Among others, these include a belief that the most important objective of the course is student mastery of the content of the course. They also tend to believe that other objectives, particularly those dealing with the broader, cultural aspects of physics, are of minimal importance; most employ lecturing and problem-solving with minimum use of demonstrations or references to the student laboratory as their primary teaching methods.

Methods and Classroom Technologies for Teaching High School Physics

The term "learning materials" includes a whole range of written, visual, and other materials such as computer programs, film cartridges, audio tapes, video tapes, and laboratory and demonstration equipment. Teachers are like students in that they vary widely in their goals, needs, background, interests, abilities, response to various media, and other factors that influence learning. A textbook or any other single learning material, device, or approach simply cannot serve such diversity (Rutherford, 1971). According to Educating Americans for the 21st Century (National Science Board Commission, 1983), modern information technologies offer a tremendous potential for improving education and the educational process. Computers, for example, have become universal devices with applications in numerous areas. Television--via satellite, cable, and closed circuit--provides an unprecedented number of options in the transmission of information to almost any location. Interactive communications, coupling television with microprocessor and videodiscs, are offering new and exciting possibilities for the improvement of teaching and learning.

> The psychology of learning supports the thesis that variety of materials promotes better learning. More of the senses are stimulated, and more avenues of learning are activated. Audio-visual equipment and materials continue to gain in sophistication. New techniques with overhead projectors, film-loop projectors, and single-concept films are finding increasing popularity. Individual differences are being served better by these materials, and individualized instruction is enhanced by more flexible audio-visual aids. (Sund & Trowbridge, 1973, p. 462)

Trowbridge, Bybee, and Sund (1981) have reminded us of the purposes various materials can serve in the process of educating students:

1. More of the students' senses are stimulated by teaching aids. They frequently activate the avenues of learning involving sight, sound, touch, smell, and taste. Combinations of senses are appealed to more often.
2. Teaching aids maintain interest. Students are likely to be in a receptive frame of mind for maximum learning.
3. Teaching becomes less fatiguing when a variety of methods and materials is used and the teacher's enthusiasm is maintained.
4. Individual differences are most adequately served by a variety of teaching aids. Students frequently learn better by one method than by another.
5. Teaching aids provide opportunities for frequent changes of pace, which is particularly useful in junior high school teaching.
6. Specific materials designed for specific teaching tasks are more effective because of their refined nature. For example, a well-designed model of certain geological features may illustrate a point

> better than a photograph or in some cases better than an actual field trip to the scene. (p. 210)

Klopfer (1980) pointed out that convenient, affordable videotape and videodisk playback systems promise to make television a powerful instructional alternative via either playback systems or direct broadcast.

The actual learning process in science courses can and should involve students with hands-on and open-ended laboratory learning experiences (Kyle, 1980). Serlin (1976) believes that since science is essentially a model-building enterprise, science teaching should emphasize processes such as hypothesizing, experimenting, and inferring. Physics educators have suggested that the teaching of such processes should be a major thrust of the physics laboratory. Serlin suggested that laboratory and hands-on activities will help develop the concrete experiences needed for a student to move toward more formal cognitive thinking. Spears and Zollman (1977) pointed out that laboratory instructional strategies may be separated into two categories: those that place emphasis on verification of physical principles and those that use the inquiry approach to discover various physical principles. The prevalent practice in physics laboratories is the emphasis on fact gathering and principle verification which are usually carried out using a deductive, "cookbook" laboratory approach (Serlin, 1976). The question of structured versus unstructured laboratories has been raised and the arguments of Gagné suggest that some type of initial structure is important (Spears & Zollman, 1977).

According to Bates (Rowe, 1978), lecture, demonstration, and laboratory teaching methods appear equally effective in transmitting science content. However, some types of inquiry-oriented laboratory activities appear better than lecture/demonstration or verification labs for teaching the process of inquiry. Laboratories also appear to provide opportunities for a wider variety of students to be successful in science. In a study of laboratory instruction methods, Kellogg (1967) found that the prospective teachers assigned to both the laboratory-discovery group and the demonstration-discussion group indicated that if they had been given an opportunity to select their group, most would have chosen the laboratory-discovery group. Kyle (1980) noted the relatively small amount of time that students in college science laboratories actually spend experimenting. Thirty-six percent of the lab time observed was spent experimenting while instructors spent 25.3% of the time transmitting information.

A demonstration has been defined as the process of showing something to another person or group. Demonstrations, in addition to being used for simple observation or verification, may also be conducted for experimental purposes. Inductive demonstrations can be given by the instructor asking several open-ended questions and have the advantage of stressing inquiry. Demonstrations can be justified for the following reasons: (a) lower cost, (b) availability of equipment, (c) economy of time, (d) less hazard from dangerous materials, and (e) showing the use of equipment (Trowbridge, Bybee, & Sund, 1981).

The increasing importance of computers in the world today suggests that computer education is an important part of science education. Computers enhance the educational methodology and technology available to teachers. Computers have the ability to individualize instruction thus freeing the teacher to practice more flexible types of instruction. The computer can enhance problem-solving, simulations, and verbal skills, and in the science lab the computer can aid in collecting, analyzing, graphing, and storing of data. Walker (1983) has identified seven major ways that microcomputers can contribute to education:

> 1) more active learning, 2) more varied sensory and conceptual modes, 3) less mental drudgery, 4) learning nearer the speed of thought, 5) learning better tailored to individuals, 6) more independent learning, and 7) better aids to abstraction. (p. 103)

A study by Kulik, Bangert, and Williams (1983) found that computer-based teaching raised students' scores on final examinations by approximately .32 standard deviations, or from the 50th to the 63rd percentile. In addition, students who were taught on computers developed positive attitudes toward the courses they were taking, while the computer substantially reduced the amount of time needed for learning. In a study of the effectiveness of computer simulations, Lunetta found the following:

> Three teaching methods were used. The <u>computer</u> group viewed film loops and worked with the computer interactive dialogues. The <u>simulation</u> group used film loops, simulated data, problem sheets, and teacher interaction. The <u>control</u> group performed the PSSC laboratories and worked with the teachers in a standard presentation. The computer group achieved significantly higher scores on measures of content learning than did the simulation group, while both the computer and simulation groups were significantly superior to the control group. The control group also required 3.2 times longer to complete the unit than did the simulation group, and 8.3 times longer than the computer group. This investigation should be kept in mind as a possible indicator of future instructional technology. The question of cost effectiveness of the three strategies is especially relevant, and should be considered in any future investigations. (Rowe, 1978, p. 61)

Shavelson (1984) found that teachers want computer software which is firmly grounded in important concepts and facts in the subject matter and closely coordinated with textbooks and other instructional materials. They also found that teachers want software which uses graphics and goes beyond the "electronic workbook" to use the computer's capabilities effectively. The study recommended that staff development microcomputer courses include the following topics: "operation of the microcomputer, selection and evaluation of courseware, instructional uses of microcomputers, computer literacy, and methods for integrating microcomputers into the ongoing curriculum" (p. 41).

Inquiry Approach to Secondary Physics Teaching

What is discovery or inquiry? Many educators use these terms interchangeably, whereas others prefer to differentiate their meanings.

> It may be said that inquiry is taking place any time the child is required to go beyond the presented information to gain new insights. A lesson wherein a teacher presents a problem to children through demonstration, anecdotes, pictures, graphs, or tables, and conducts a discussion which leads to some generalization may be called a rational inquiry

> lesson. The children reason their way to gain fresh insights from the discussion. (Esler, 1973, p. 19)

To Trowbridge, Bybee, and Sund (1981, chap. 13), discovery occurs when an individual is involved in using his or her mental processes to discover some concept or principle. Inquiry teaching is built on and includes discovery but also includes the process of originating and investigating problems, formulating hypotheses, designing experiments, gathering data, and drawing conclusions about that data. Scientific inquiry should not be construed as synonymous with investigative, experimental, or discovery methods of science teaching. Three main themes of inquiry include (a) general inquiry processes, (b) science process skills, and (c) nature of scientific inquiry.

> General inquiry processes include strategies such as problem-solving, use of evidence, logical and analytical reasoning, clarification of values, decision-making, and safeguards and customs of inquiry. Science process skills include the usual range of science processes, such as observing, measuring, interpreting data, etc. The nature of scientific inquiry is affected by the structure of scientific knowledge and by assumptions about the natural world such as causality and non-capriciousness. . . . A teacher equipped to conduct inquiry would possess questioning skills that

> are divergent, have a knowledge of science processes and have the capability of conducting a student-centered inductive approach. (Sweitzer, 1982, p. 7)

Kyle (1980) noted that the essence of inquiry teaching is arranging the learning environment to facilitate student-centered instruction while giving sufficient guidance to insure direction and success in discovering the topic under study. The teacher must have the ability to ask questions and to stimulate and facilitate creative and critical thinking. What does inquiry instruction "look like"? Welch, Klopfer, Aikenhead and Robinson (1981) explained that inquiry instruction uses a variety of methodologies such as discussions, investigative laboratories, student-initiated inquiries, lectures, and debates. Teachers serve as role models and it is easy for students to ask questions. Risk-taking is encouraged and there is a high level of student-student interaction. Science content and processes are inseparable. "How do we know?" enters many conversations. Classroom climates stimulate a thorough, thoughtful exploration of topics, rather than trying to finish the text. Shymansky and Penick (Blosser & Helgeson, 1984) in a study of teaching behavior and student performance in science classrooms found:

> One -- the teacher dominated strategy resulted in students being dependent on the teacher,

> Two -- students view science and scientist more positively in a student centered environment,
>
> Three -- students show more on-task behavior in student centered environment,
>
> Four -- student creativity and problem solving is higher in student centered environments. (p. 17)

Inquiry discussions motivate students and involve them more than do lectures. When leading inquiry-oriented discussions, the instructor should question and give minimal information. The type of question asked helps students discover the concept or principles involved. A good technique for starting a discussion is to use a demonstration or overhead projection pertaining to a topic to be studied. Discussion is also an excellent vehicle for review, both in class and laboratory work (Trowbridge, Bybee, & Sund, 1981). Sund and Trowbridge (1973) showed that two advantages of discussion are that students become more interested because they are involved, and that as a result, the teacher receives more feedback from the students.

In a study comparing discovery and traditional teaching methods, Henkel (1966) found that all students gained on a "traditional" physics achievement test, but only those of the traditional lecture and laboratory group showed significant gain on the achievement test. Pickering (1970) in a study of the effects of inquiry experiences on prospective elementary teachers found that when inquiry-laboratory, inquiry-demonstration, or lecture techniques were used there was no significant difference in any of the areas compared except the inquiry-laboratory group was significantly superior to the other two groups on attitude toward teaching science. Lawfer (1974), in a study comparing the effectiveness of the lecture demonstration and inquiry method of teaching science to prospective teachers, found no significant difference in achievement gains between groups.

What do teachers perceive to be the limitations of teaching science as a process of inquiry? A group of the prominent science educators under the auspices of Project Synthesis identified the following limitations: (a) lack of training, (b) lack of time, (c) lack of materials, (d) lack of support, (e) over-emphasis on assessing content learning rather than process learning, and (f) excessive difficulty of the inquiry approach (Rakow, 1986). Klopfer (1980) observed that science teachers tend to be tied to the text and tend to place emphasis on students acquiring information, rather than understanding science concepts. There is a discrepancy between general statements about the importance of inquiry and the degree to which it is practiced in the classroom. While many teachers make positive statements about the value of inquiry, they often feel more responsibility for teaching facts. According to

Anderson (Harms & Yager, 1981) a second major reservation of teachers is that inquiry instruction causes confusion and is too difficult for all but the very brightest students. Many teachers and parents consider the primary purpose of science education to be preparation of the student for the next level of schooling.

Inservice

Kane and Chase (1983) stated that inservice education now seems integral to improving the quality of teaching in our schools.

> In 1969 more than 10% of all teachers were first-year teachers and issues of quality were addressed in pre-service settings. Now that new teachers make up less than 5% of the teaching force each year, quality must be addressed through inservice education. (p. 6)

Evans (Kane and Chase, 1983) predicted that the 1980s will become known as the decade of inservice education just as the 1960s is known as the decade of course content improvement projects.

Science teacher inservice education is seen as an important and necessary factor for improving science teaching and learning. Spector (1987) wrote that one of the complicating factors in designing inservice education opportunities for teachers is the diversity of expertise which exists in the potential client audience for whom the inservice is designed. Within the profession science teachers have a variety of academic credentials and needs. There are (a) those with current degrees in science education who are high performing and want to continue studying, (b) those with degrees in science education from many years ago who need updating, (c) those with degrees in science who need certification to teach science, and (d) those with undergraduate non-science degrees who require certification and need a stronger base. The teachers in the last category constitute a major new audience for inservice teacher education.

George and Nelson (1971) pointed out that the relationships between the variables, teacher experience, type of inservice training, and success in inservice work as measured by achievement tests need to be investigated more thoroughly. Willson and Lawrenz (1980) reported that the National Science Foundation has spent hundreds of millions of dollars for teacher training in science and mathematics. Most of the money has been used to support various training institutes; research on the effects of these institutes indicate that secondary science student achievement generally improves as a result of teacher institute attendance.

Miller (1978) noted that as the world's population continues to increase, the resources available for education will not keep pace with the demand. Therefore, there will be a tremendous increase in concern for efficiency, relevance, and accountability, and emphasis will be placed on instructional cost-effectiveness of inservice for teachers. Several conclusions were derived from the data collected in a study by Barnett (1976): (a) workshops that facilitate teachers' active participation can enhance transfer of this experience to the classroom, (b) students' use of science equipment and their science process skills are enhanced by teachers who have experienced similar experiences, and (c) effective inservice programs are needed to develop the teaching competencies necessary for implementing educational reform. Barnett's second conclusion is supported by a study by O'Sullivan, Piper, and Carbonari (1981) which supports the basic contention that inservice can have a positive impact on student achievement.

Studies by Rubba (1981, 1982) report that while physics teachers have the special inservice need of the more effective use of instructional materials, chemistry teachers who frequently teach physics have the additional inservice need for content updating in physics. While self-identification of needs helps to make inservice sessions more palatable for most participants, external identification of inservice needs may also be necessary to improve teacher effectiveness.

> For example, if physics teachers are relying heavily on mathematical abstractions, they may be turning off many students. The teachers may need to be told of this problem. Inservice sessions might be necessary to help mathematically oriented physics teachers convert to other approaches. (Blosser & Mayer, 1983, p. 88)

Lawson, Costenson, and Cisneros (1986) described one study where teachers and principals were in agreement on three of their five top-ranked topics for which inservice is needed. These included using effective laboratory activities, planning and organizing instruction, and using a variety of instructional strategies.

In a meta-analysis by Enz, Horak, and Blecha (1982), it was found that teachers made knowledge gains as a result of science inservice projects, and based on an analysis of their data, the following recommendations were made:
(a) future studies should be conducted to determine the long-term effects of science inservice projects, and
(b) since the majority of the studies reviewed contained insufficient data for evaluation, future science inservice projects should collect sufficient data for evaluation. Bowyer, Ponzio, and Lundholm (1987) in a synthesis of the research on staff development suggested that for maximum usefulness, staff development should be individualized and be ongoing throughout the academic year. They asserted

that participants should be involved in the selection, planning, and conducting of various staff development activities. Neither graduate courses nor one-shot workshops have proven effective; however, there are several factors which do distinguish successful inservice from less successful activities. These include individualized activities, self-instruction, and teacher involvement in planning the workshop activities (Blosser, 1983). According to Joyce and Showers (1980) when inservice workshops are planned, five components of effective inservice training should be included:

> a) Presentation of theory or description of a skill or strategy;
>
> b) Modeling or demonstration of skills or models of teaching;
>
> c) Practice in simulated and classroom settings;
>
> d) Structured and open-ended feedback (provision of information about performance);
>
> e) Coaching for application (hands-on, in-classroom assistance with transfer of skills and strategies to the classroom). (p. 380)

CHAPTER III

RESEARCH DESIGN

This study used a battery of physics achievement tests to measure and compare content knowledge gains of 22 physics teachers who participated in an inquiry inservice workshop. The objective of this study was to determine to what extent inquiry instruction also taught the necessary content to improve conceptual and analytical "standardized test" scores. Additional investigations conducted in the study included the following:

1. To determine the content knowledge performance of TPTT participants in each of five physics topic areas on a written pretest based on the minilesson objectives.
2. To determine and compare the short-term content knowledge performance gains in the five topic areas as a result of the minilessons by comparing the pretest results with the performance on a written posttest given at the conclusion of the summer workshop.
3. To determine the long-term content knowledge gains of the participants as a result of the summer workshop by comparing the pretest results with the performance on a written posttest given during the fall workshop.
4. To determine the content knowledge gains in the topic areas in which the participants developed and taught

materials with objectives similar to those of the minilessons.

5. To determine the relationship of formal physics education to content knowledge gains.
6. To determine the relationship of number of years experience teaching physics to content knowledge gains.
7. To compare the performance of participants on conceptual questions and analytical problems on the test batteries.

Hypotheses

1. High school physics teachers who participate in the inservice program, Teaching Physics Teachers with Technology, will have a statistically significant increase in the content knowledge test scores between Tests I and II.
2. Physics teachers who participate in the TPTT inservice program will have a statistically significant increase in the content knowledge test scores between Tests I and III.
3. Teachers' content knowledge test scores will improve significantly in content areas where participants developed and taught modules (PTM) in which the teaching objectives were similar to those objectives being tested in that content area.

4. Performance on Test Battery I will be higher for participants with physics degrees than for those participants who do not hold physics degrees.
5. The scores of participants with physics degrees will increase significantly more between Test Batteries I, II, and III than the scores of teachers with less physics preparation.
6. Performance on Test Battery I will be higher for participants with more physics teaching experience than for those participants with less physics teaching experience.
7. The scores of participants with more physics teaching experience will increase significantly more between Test Batteries I, II, and III than the scores of teachers with less physics teaching experience.
8. There will be no significant difference between conceptual test scores and analytical test scores.

Experimental Design

To investigate the various hypotheses, the following experimental designs were employed: (a) a one-group nondesign with a correlation study, and (b) a quasi-experimental untreated control group design. Both experimental designs utilized a pretest (Test Battery I), short-term posttest (Test Battery II), and long-term posttest (Test Battery III).

The one-group design and the correlation studies were useful in investigating the hypotheses (1, 2, 4, 5, 6, 7, 8) concerning the whole group (i.e. initial results and how various groups of participants with different levels of physics academic preparation did on Tests I, II, and III). This design was necessary in that the number of high school physics teachers statewide is small.

The quasi-experimental untreated control group design investigated the hypothesis (3) concerning the topic areas where part of the group received a treatment in that particular topic area which the other part of the group did not receive (i.e., some participants taught some of the material to be tested on Test III in the fall and that might have reinforced and/or increased the content knowledge between Test II and Test III of those participants in their respective materials development areas). Since the participants were chosen instead of selected at random for the workshop, the design for this part of the study had to be quasi-experimental.

Tests I, II, and III were written instruments at the introductory precalculus college level based on the lesson objectives of each of the five minilessons. This level of testing was chosen because most science education majors are required to have at least eight semester hours of noncalculus-based introductory level physics. Test Batteries I and III contained all five subtopic tests, Test

Battery II consisted of one-half of the teachers taking the thermal and electricity and magnetism exams while the other half took the optics, modern, and mechanics exams. In each content area the same test was used for Test Batteries I, II, and III.

Operational Definition of Terms

"Teaching Physics Teachers with Technology" (TPTT): A 3-year NSF grant with the Department of Physics at North Carolina State University for a series of three workshops each year for 25 North Carolina high school physics teachers each year for a total of 75 teachers. This represents approximately 25% of the high school physics teachers in North Carolina. The workshop helped teachers become users of computers and other more familiar resources in their teaching. The workshop used a variety of teaching strategies to integrate laboratory, demonstration, and other instructional modes to demonstrate teaching while using topic areas with which physics teachers were less familiar.

Minilessons: Two-hour hands-on inquiry lessons using a number of classroom technologies such as computers with various interfacing devices to teach "model" inquiry lessons in targeted physics content areas. Each of these sessions was video taped for future reference. The five sets of minilesson objectives are listed in Appendix A.

Subtopics: These areas were taught in the five minilessons:

Topic Area	Subtopic Area
Electricity and Magnetism	Capacitance
Thermodynamics	Specific Heat
	Thermal Transfer
Waves and Optics	Reflection and Refraction
Modern Physics	Radioactivity
Mechanics	Circular Motion

Materials Development: The TPTT workshop participants were divided into five small groups to develop "Physics Teaching Modules" (PTM) in one of the areas of mechanics, waves and optics, thermodynamics, electricity and magnetism, and modern physics. These PTM were to utilize several classroom technologies (i.e., computer-based lessons, video, laboratory activities, and demonstrations) and a variety of teaching strategies requiring several class periods of instruction. These materials were to be "field-tested" by each participant prior to the fall workshop. The guidelines given to the participants for PTM development are given in Appendix B.

Parallel Module Groups: This refers to the electricity and magnetism and thermodynamics module groups since they choose to develop materials on topics which expanded on the same objectives as those taught in their respective minilessons.

Short-term Retention: This refers to the period between administering Test Battery I at the beginning of the 5-day summer workshop and Test Battery II at the conclusion of the summer workshop.

Long-term Retention: This refers to the period of approximately 3 months between administering Test Battery I at the beginning of the summer workshop and Test Battery III during the fall workshop.

Content Knowledge Tests: A battery of five content knowledge tests including multiple choice, definitions, derivations, and analytical word problems based on the minilesson objectives in the five subtopic areas taught. Most of the questions were either conceptual or analytical. Each test contained 13 to 17 introductory precalculus college level questions and problems. The batteries were administered three times during the program. All five tests were administered to all 22 workshop participants in two 1-hour sessions at the beginning of the summer week-long workshop (Test Battery I). The second test battery (Test Battery II) was administered in a 1-hour session at the conclusion of the summer workshop. Half of the participants took the capacitance and thermal tests while the other half of the group took the other three tests. The third testing session (Test Battery III) occurred during the fall workshop where eighteen of the participants took all five tests in two 1-hour sessions. Copies of the five tests used are in Appendix C.

Physics Teaching Experience: The number of years the teacher has taught at least one class of physics at the secondary level or higher.

Physics Academic Preparation: This refers to the type of certification the teacher has with physics certification or a physics degree being the highest level of preparation (major), science certification with a minor in physics being second (minor), and no science or physics certification or degree would be the lowest level of formal academic preparation (minimum).

Conceptual Test Scores: The score on the conceptual multiple-choice questions on each of the five tests. The conceptual questions used to calculate the conceptual test scores are listed in Appendix D.

Analytical Test Scores: The score on the analytical problems on each of the five tests. The analytical problems used to calculate the analytical test scores are listed in Appendix D.

Sample Description

Twenty-two North Carolina high school physics teachers participated in this study. The group consisted of 15 females and 7 males. They were all self-selected participants in the TPTT inservice workshop sponsored by

North Carolina State University. Five of the workshop participants have a major at either the bachelor's or master's level in physics, six have at least 18 semester hours or the equivalent to a minor in physics, and eleven workshop participants have taken fewer than 18 semester hours in physics. The workshop participants also consisted of 7 teachers with 0 to 3 years of experience teaching physics, 7 teachers with 4 to 10 years of experience teaching physics, and 8 teachers with 11 or more years teaching physics.

A randomized group or a second equivalent control group was not practical because the total number of teachers teaching physics in North Carolina is very small and the number of those teaching with equivalent backgrounds to the experimental group is much smaller still. In a survey by Johnston (1987) of the 326 teachers teaching physics in North Carolina, approximately 40% returned their survey, and only 13 of those responding had a major or minor in physics.

Experimental Treatment

There were three experimental treatments in this study. The first and most direct treatment was the series of five 2-hour minilessons taught by the workshop instructors during the first part of the 5-day summer workshop. The second treatment was the development of

"Physics Teaching Modules" (PTM) by small groups of four or five participants during the second portion of the summer workshop. The materials developed by the participants should have reinforced the content tested if the objectives of the materials were similar to the minilessons objectives. Any content knowledge gains as a result of treatments one and two should show up in the results from both tests II and III. The third treatment was the teaching of the PTM between the summer and fall workshops in the subtopic areas for which modules were developed. The PTM on electricity and magnetism, and thermodynamics had objectives similar to those measured by the respective tests. Therefore, the workshop participants in the parallel module groups taught materials covered on their respective parts of the test batteries between Tests II and II.

The course objectives as prepared by each of the minilesson instructors are listed in Appendix A, and a sample lesson plan (optics) is listed in Appendix E. The workshop schedules for all three sessions (spring, summer, and fall) are given in Appendix F.

Research Instruments

The test batteries were administered on three occasions to measure the participants' knowledge in the five minilesson topic areas. After searching for standardized tests for which the validity and reliability had been determined and which would be sensitive to measuring solely the content knowledge in the subtopic areas to be taught in the workshop minilessons, the author concluded that those types of standardized tests were unavailable.

The instrument used in this study was developed in consultation with several individuals. It was important to balance the need for a sufficient number of test items while not making the battery so long as to cause the participants to distort the results for affective reasons. It was determined that each of the five tests would be paper, pencil, and calculator tests and would have between 13 and 17 questions. The tests included conceptual and analytical multiple-choice questions, several simple derivations and definition-type short-answer questions, and analytical word problems. These questions and problems were at a precalculus-based introductory college level. This level of testing was chosen because most science education majors are required to have at least eight semester hours of noncalculus-based introductory level physics.

The administration of Test Batteries I and III were to include all five tests being given in two 1-hour sessions with 34 questions on capacitance and thermal energy given in the first testing session and 40 questions on the other three areas given during a second testing session. Test Battery II was administered at the end of the week when fatigue might have become a factor. For this reason it was determined that half of the group would be given the capacitance and thermal tests while the other half would be given the three shorter tests.

To enhance the reliability of the instrument, efforts were made to see that test questions were unambiguous and covered a spectrum of level of difficulty. While the five tests (one for each topic studied) were dissimilar, 13 to 17 test items were used to measure content knowledge changes in each topic area.

The process of developing the research instrument began with each of the five minilesson instructors developing lesson objectives and sending copies to the author. The author searched for examples of "standardized" type questions from numerous physics textbooks at the precalculus introductory college level and developed the instrument based on these examples and the minilesson objectives. The instrument was reviewed by a senior faculty member of the Appalachian State University Department of Physics and Astronomy, Dr. Walter Connolly, who made a number of useful suggestions for improving the instrument. The five individual tests were then given to the respective minilesson instructors for editing and approval. Again some useful changes were made. The five tests are presented in Appendix C. The tests were finalized and each instructor returned a copy to the workshop director and a completed answer key to the evaluator who double-checked all answers and for consistency scored each battery of tests. While questions were scored objectively, they were not "weighted". Therefore, each question had the same percentage score on any given test. Each question was scored either a 5, 4, 3, or 0 based on its "degree of correctness". A score of 5 represented a completely correct answer, while 4 and 3 represented "significantly" correct answers with only one or two small mistakes. Zero was the score given to incorrect or no response answers. This allowed the advantage of looking at the data several ways such as counting only 5s as correct, looking for "any" improvement, or possibly counting 3 through 5 as correct. In this study all correct responses (3s, 4s, and 5s) were counted and raw percentage correct scores were calculated for each test or subsections of tests as the number correct divided by the total number of questions and problems in that section or test.

Individual scores varied but were generally in the middle range, with few 100s or zeros on the tests in Test Battery I. It was difficult to pitch the test level the first time with no previous examples from which to work.

Data Collection

The data collection process consisted of measuring the physics content knowledge of the workshop participants in the five areas studied. These measurements took place at the beginning of the summer workshop (Test Battery I), after the minilessons and materials development at the end of summer workshop (Test Battery II), and at the fall workshop (Test Battery III) after the teachers had taught the materials they developed as well as possibly some other areas studied in the minilessons.

While Test Batteries I and III consisted of administering all five subtopic tests to all the participants, Test Battery II varied in that half of the participants were given the two longer tests (electricity and magnetism, and thermodynamics) while the other half of the group was given the three shorter tests (modern physics, mechanics, and optics). The workshop director administered the tests and briefly discussed the importance of evaluation. Test directions were simple. Participants were instructed that the multiple-choice questions could have more than one correct answer, all correct answers on each question should be circled, work on problems should be shown, and approximately one hour would be given to complete the test, but more time would be given if needed. The participants were asked to do their best. For reasons of confidentiality each test was identified only by the last four digits of each participant's social security number.

Each participant was asked for background information concerning his or her (a) degree, (b) teaching certification, (c) years of teaching experience, (d) years of physics teaching experience, and (e) topics taught in the fall before the fall workshop. The background information was to be used in various analyses of the data.

The participants did not have an opportunity to study the results of their individual tests, and no feedback about the tests or test scores was given. This was an effort to reduce the learning of the content knowledge due to the testing process. To assure consistency in test conditions the workshop director and investigator administered all tests.

Analysis of Data

The raw scores represent the percentage scored as correct on each of the different tests administered. The raw test scores are presented in Appendix G. The raw data were organized and analyzed in the following categories: (a) test topic, (b) electricity and magnetism and thermodynamics parallel module group respective test scores, (c) academic preparation, (d) physics teaching experience, and (e) conceptual versus analytical results.

To test for statistical significance between pretests and posttests, a one-tailed dependent _t_ test was used (Best, 1981). Because the sample size was small in most of the comparisons, rather than using the normal probability table, the t-table Student's Distribution developed by William Sealy Gosset was used to determine statistical significance (Best, 1981). The dependent _t_ test required the use of the Pearson Correlation Coefficient in its calculation. While these values are not given they generally ranged from .60 to .90 between various sets of pretests and posttest means.

Each of the data tables is shown in pairs. The first table in each pair contains the mean score for each test as well as the number (n) taking each test. The second table contains the mean change in content knowledge score between the two tests, the _t_ score for that change, and the level of significance for that change. The analyses reflected in the odd-numbered tables are simply descriptive; they reflect the participants' performance on each of the three individual tests. The even-numbered tables report the inferential analysis; participants' scores are compared on Test I to Test II and on Test I to Test III.

Summary

This chapter presented the main purpose and objectives of the study, the eight hypotheses, and the experimental designs used in the study. Operational definitions of terms, the sample population, and the experimental treatment used in the study were described. The design of the research instrument, data collection, and data analysis were also discussed in this chapter. Statistical analysis and results will be presented in Chapter IV.

CHAPTER IV

ANALYSIS OF DATA

Objectives of the Study

The primary objective of this study was to determine to what extent inquiry instruction also taught the necessary content knowledge to improve conceptual and analytical standardized exam-type scores. The study examined the content knowledge level of the group prior to participating in the workshop, short-term gain in content knowledge as a result of the inquiry minilessons, and content knowledge retention over a 3-month period of time. The content knowledge gains in the areas in which the participants had developed modules with objectives similar to those of the minilessons were studied, as well as the relationships of formal physics education and number of years of experience teaching physics to content knowledge gains. The results between conceptual questions and analytical problems were compared.

Statistical Treatment of the Data

The raw scores represent the percentage scored correct on each of the different tests administered. The raw test scores are presented in Appendix G. This chapter presents descriptive statistics in tabular and graphical form according to (a) test topic, (b) electricity and magnetism and thermodynamics parallel module group respective test scores, (c) physics academic preparation, (d) physics teaching experience, and (e) conceptual question versus analytical problem results.

In the first four of these five data sets, initial results are listed in a table as a mean percentage correct of all those taking the test and then the number (n) completing each test. The second table in each of the first four sets gives the mean score increase between Tests I and II as well as Tests I and III of all those taking the two tests being compared. To test for statistical significance between pretests and posttests, a one-tailed dependent _t_ test was used. Because the sample size was small in many of the comparisons, the _t_ table, "Student's Distribution," developed by William Sealy Gosset was used to determine statistical significance (Best, 1981). The dependent _t_ test used required the use of the Pearson Correlation Coefficient in its calculation. While values are not given here in the data, they generally ranged from .60 to .90 between various sets of pretests and posttests.

The following tables are shown in pairs. The first contains the mean score for each test while the second table contains the mean change in content knowledge score between the two tests, the _t_ score for that change, and the level of significance for each _t_ score. The difference between the mean scores given in the first of both tables may not have the same value as listed in the second table. The analyses reflected in the odd-numbered tables are simply descriptive; they reflect the participants' performance on each of the three individual tests. The even-numbered tables report the inferential analyses; participants' scores are compared on Test I to Test II and on Test I to Test III.

Descriptive Analysis

Examination of the data reveals the following general trends:

1) Within the topical areas, participants scored consistently higher on the thermodynamics portion of all three test batteries. Mechanics and electricity and magnetism were the lowest or next lowest on all three test batteries. All five topical areas demonstrated a significant gain in content knowledge scores between Test Batteries I and II and no significant gain in scores between Test Batteries I and III.
2) When comparing the results of those module development groups whose module objectives were similar to the minilesson objectives tested (electricity and magnetism and thermodynamics), the increases in the parallel module groups' mean scores were not

significant between Tests I and II, but were approximately equal to or larger than the total group's mean increases. The mean gains between Tests I and III were not significant, but were much greater for the parallel module groups than for the whole group.

3) Level of physics academic preparation was a factor in the initial mean content knowledge scores. While all groups made significant gains between Tests I and II, those with the poorer physics backgrounds made the most significant gains. None of the academic preparation groups had a significant gain between Tests I and III.

4) Years of teaching physics experience was a factor in the initial mean content knowledge scores and the most experienced group scored the highest on all three test batteries. While Tests I to II gains were significant for all groups and were not significant for any of the groups between Tests I and III, the least experienced group had the largest gains between Tests I and II as well as Tests I and III.

5) The participants definitely demonstrated a tendency to answer a higher percentage of correct responses on the conceptual questions than on the analytical problems.

Comparisons by Subject Areas

Table 1 shows mean scores on each of the tests in each of the topic areas as well as the number of workshop participants who actually took each test. Figure 1 shows that electricity and magnetism was the lowest initial mean score while thermodynamics had the highest initial mean score. Thermodynamics had the highest mean score on all three test batteries. Thermodynamics mean scores were 67, 75, and 78 on Tests I, II, and III, respectively. The Test I low mean score was 37 in electricity and magnetism. The Test II low mean score was 55 in mechanics. The Test III low mean score was 47 in both electricity and magnetism and mechanics. The mean scores for all five tests combined were 51, 66, and 58 on Test Batteries I, II, and III, respectively.

Table 2 shows the increase in scores of participants who took Tests I and II as well as participants who took Tests I and III in each of the topical areas. Figure 2 illustrates the largest increase in mean scores was 22 (between Tests I and II) and 5 (between Tests I and III) in the electricity and magnetism, the topical area with the lowest initial mean score. The increase in scores between Tests I and II is at the .05 level of significance for the areas of modern and optics while the level of significance is at the .01 level for the other three topical areas. The

Table 1

Mean Performance Scores by Topic

	TEST I		TEST II		TEST III	
	SCORE	n	SCORE	n	SCORE	n
TOPIC						
MECHANICS	43	22	55	11	47	17
MODERN	56	22	67	10	64	17
OPTICS	54	22	70	9	54	19
E & M	37	21	61	10	47	16
THERMAL	67	22	75	12	78	17
MEAN SCORES FOR ALL TOPICS	51		66		58	

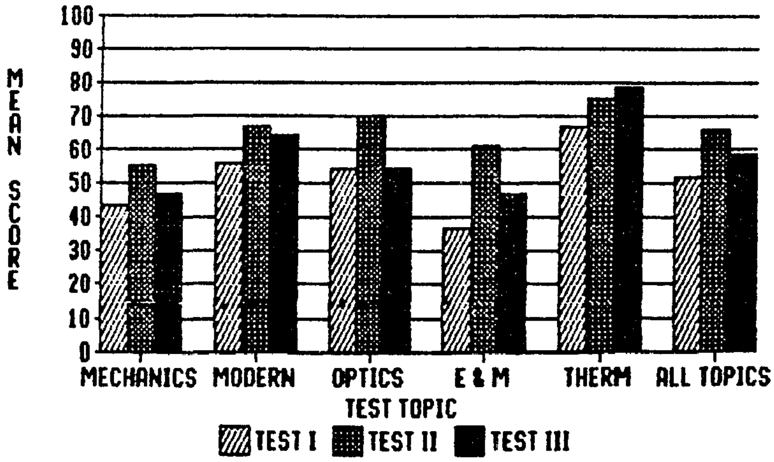

Figure 1. Mean Score as a Function of Test and Test Topic

Table 2

Mean Performance Score Gain (Between Tests) by Topic

	TEST I TO TEST II		TEST I TO TEST III	
	GAIN	T TEST SCORE	GAIN	T TEST SCORE
TOPIC				
MECHANICS	9	3.083 ***	0	.037 *
MODERN	12	1.925 **	4	1.09 *
OPTICS	11	2.156 **	-1	-.381 *
E & M	22	3.996 ***	5	.816 *
THERMAL	14	2.964 ***	3	.567 *
MEAN GAIN FOR ALL TOPICS	14		2	

Note. *p>.05. **p<.05. ***p<.01.

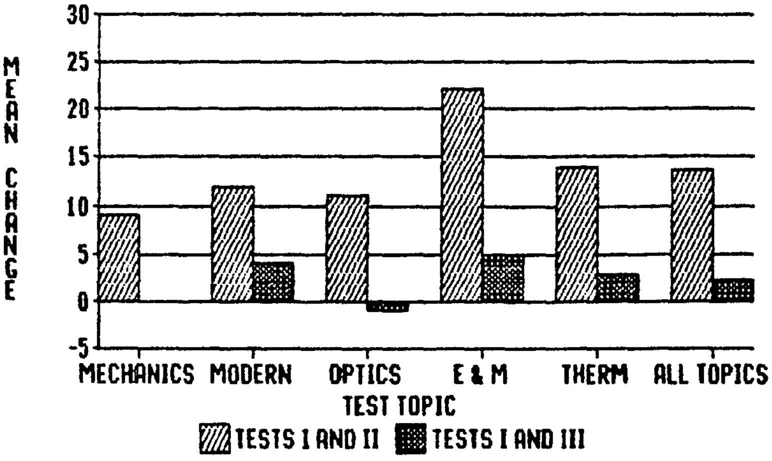

Figure 2. Mean Difference Between Tests as a Function of Test Topic

increase in scores between Tests I and III was not significant for any of the five topic areas. There was some increase in scores in the areas of electricity and magnetism (5), modern (4), and thermodynamics (3). Optics had essentially no change between Tests I and III, and mechanics had zero change as indicated on Figure 2 by the absence of a bar for the difference between Tests I and III.

Comparison of Effect of Development of a Parallel Module

Table 3 shows the electricity and magnetism, and thermodynamics mean scores for both the total group and the two parallel module groups. Both of the Test I mean scores for the module groups are the means of all the Test I scores for each parallel module group whether each individual participant took only Test II or only Test III or both Tests II and III. Figure 3 shows the scores for the electricity and magnetism module group (52, 71, 69) were higher than the total group's electricity and magnetism scores for all three tests (37, 61, 47). The thermal scores for Tests I and II were higher for the total group (67, 75, 78) but the parallel module group's (58, 61, 90) Test III mean score was higher than the total group mean. Both the general group's and the thermal module group's mean scores continued to increase with succeeding tests.

Table 3

Mean Comparison Between Whole Group and Parallel Module Group Performance

	TEST I		TEST II		TEST III	
	SCORE	n	SCORE	n	SCORE	n
TOPIC						
ALL PARTICIPANTS						
E & M	37	21	61	10	47	16
THERMAL	67	22	75	12	78	17
PARALLEL MODULE GROUP						
E & M	52	4	71	3	69	4
THERMAL	58	5	61	3	90	3

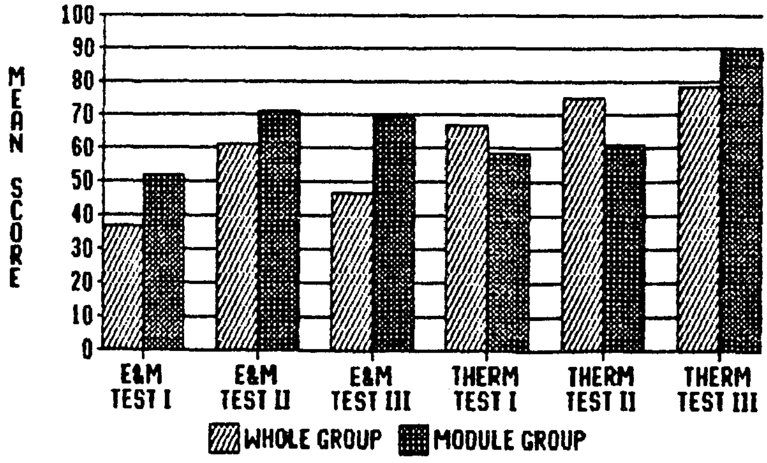

Figure 3. Whole Group Mean Scores Versus Parallel Module Group Mean Scores

Table 4 shows the increase in the mean scores of all the participants in electricity and magnetism, and thermodynamics as well as the mean scores of the participants in parallel module groups in electricity and magnetism, and thermodynamics on their respective tests. As in Table 2 the increase can be calculated only for those participants in each category who took both of the tests being compared.

Figure 4 illustrates both Tests II and III gains were larger for the electricity and magnetism module group scores (34, 17 respectively) than for the total group electricity and magnetism scores (22, 5 respectively). The total group thermodynamics Test II gains (14) were greater than the thermodynamics module group's gain (12), but the total group's thermodynamics Test III gain (3) was lower than the parallel module group's Test III gain (16). Thus the thermodynamics module group's Test III gains were larger than the total group's Test III gains and larger than the parallel module group's own Test II gain.

Table 4 indicates that while there were increases in all four scores for the two module groups, none of these increases were significant between Tests I and II or Tests I and III. The increases in the total group's scores from Tests I to II were significant, while none of the whole group's Test I to III scores were significant.

Table 4

Mean Gain Comparison Between Whole Group and Parallel Module Group Performance

	TEST I TO TEST II		TEST I TO TEST III	
	GAIN	T TEST SCORE	GAIN	T TEST SCORE
TOPIC				
ALL PARTICIPANTS				
E & M	22	3.996 ***	5	.816 *
THERMAL	14	2.964 ***	3	.567 *
PARALLEL MODULE GROUP				
E & M	34	1.739 *	17	1.108 *
THERMAL	12	1.539 *	16	2.615 *

Note. *p>.05. ***p<.01.

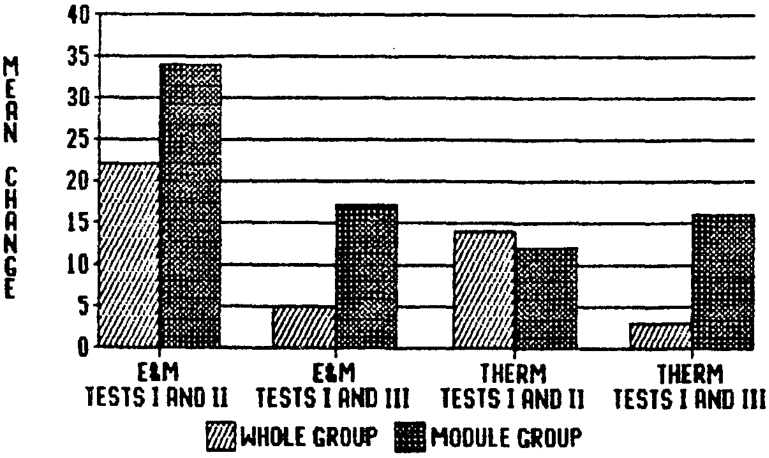

Figure 4. Mean Difference Between Tests for Whole Group Versus Parallel Module Group

The Effect of Level of Academic Preparation

Table 5 shows the mean scores of Test Batteries I, II, and III for the three levels of academic preparation. The mean scores for all three academic preparation groups, major, minor, and minimum, respectively, were 58, 53, and 46 for Test I; 66, 65, and 66 for Test II; and 74, 58, and 52 for Test III. The table also includes the number of individual test scores (n) which make up each mean. Figure 5 demonstrates that the performance of those with the equivalent to a major in physics surpassed the other two groups on Tests I and III, and those with the equivalent of a minor or at least 18 semester hours in physics performed better than those with less academic preparation on Tests I and III. All means were approximately equal for those who took Test Battery II.

Table 6 shows the increase in mean scores from Tests I to II and Tests I to III with the t-test score and level of significance for each mean score. While the increases between Tests I and II were approximately equal (Figure 6) for all three levels of academic preparation and all three scores were significant, the mean scores for those with minimum academic preparation had the most significant increase and the scores for those with a major in physics had the least significant increase.

Table 6 and Figure 6 also show that those with minimum academic preparation made the most significant short-term

Table 5

Mean Performance Scores by Academic Preparation

	TEST I		TEST II		TEST III	
	SCORE	n	SCORE	n	SCORE	n
DEGREE						
MAJOR (n=5)	58	25	66	13	74	16
MINOR (n=6)	53	35	65	15	58	28
MINIMUM (n=11)	46	49	66	24	52	43

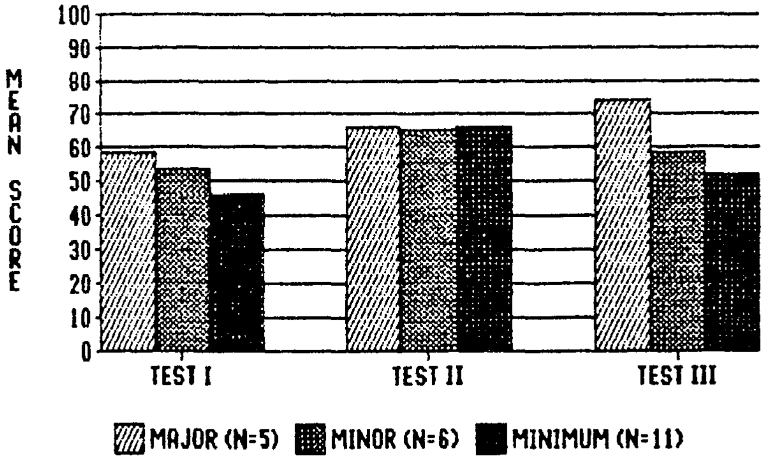

Figure 5. Comparison by Academic Preparation in Physics of All Tests Taken

Table 6

Mean Performance Score Gain by Academic Preparation

	TEST I TO TEST II		TEST I TO TEST III	
	GAIN	T TEST SCORE	GAIN	T TEST SCORE
DEGREE				
MAJOR (n=5)	14	2.787 **	5	1.404 *
MINOR (n=6)	12	3.476 ***	4	1.301 *
MINIMUM (n=11)	14	4.519 ***	0	.059 *

Note. *$p > .05$. **$p < .05$. ***$p < .01$.

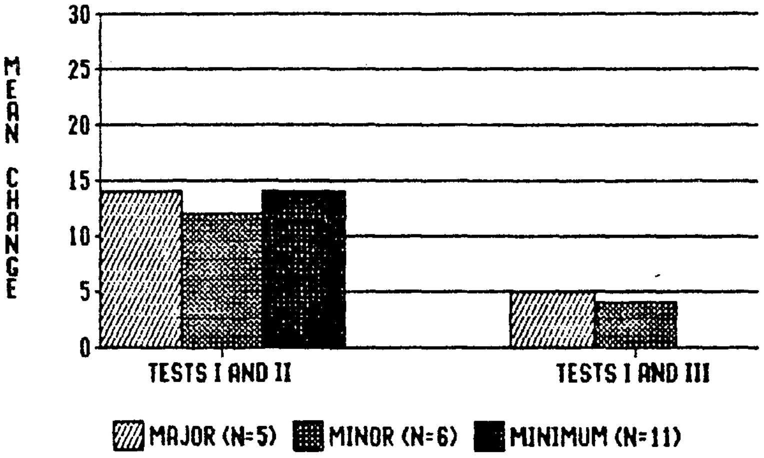

Figure 6. Mean Difference Between Tests as a Function of Academic Preparation

gains between Test Battery I and Test Battery II. There were no significant increases between Test Batteries I and III for any of the three academic preparation groups.

The Effect of Number of Years of Physics Teaching Experience

Table 7 shows the mean scores for Test Batteries I, II, and III for each of the three experience levels. The table also includes the number of individual test scores used to determine each mean. Table 7 and Figure 7 also show that those with a larger amount of experience tended to do better on each of the three test batteries. In order of most experience to least experience for Test Battery I, the mean scores were 58, 53, and 40; Test Battery II, 69, 66, and 60; and Test Battery III, 63, 57, and 52.

Table 8 and Figure 8 show the increase in the mean scores between Tests I and II and Tests I and III. The table also gives the t-test score and level of significance for each score. While those with the least experience had the largest increase between Tests I and II and Tests I and III, all three groups' increases in performance between Tests I and II were significant. Those with 0-3 years' experience mean scores increased by 16 while those with 4-10 and 11-25 years' experience increased by 14 and 11, respectively. The table also shows that for the mean increases between Tests I and III those with the least

Table 7

Mean Performance Scores as a Function of Years of Teaching Physics

	TEST I		TEST II		TEST III	
	SCORE	n	SCORE	n	SCORE	n
YEARS						
11-25 (n=8)	58	40	69	22	63	36
4-10 (n=7)	53	35	66	17	57	28
0-3 (n=7)	40	34	60	13	52	23

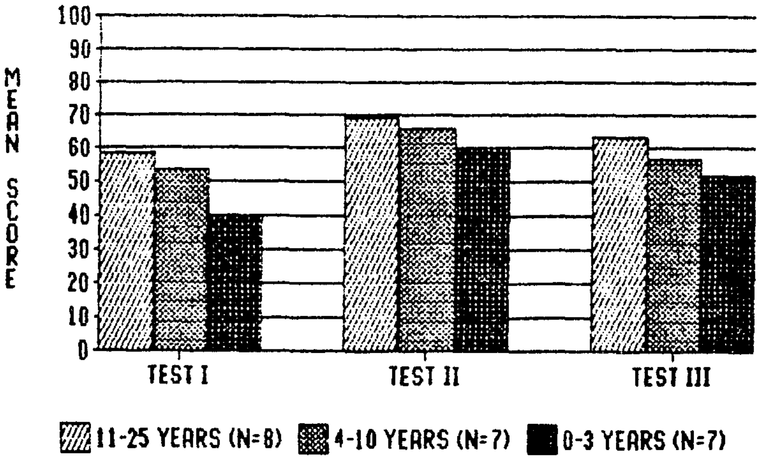

Figure 7. Comparison by Years of Teaching Physics Experience of All Tests Taken

Table 8

Mean Performance Score Gain as a Function of Years of Teaching Physics

	TEST I TO TEST II		TEST I TO TEST III	
	GAIN	T TEST SCORE	GAIN	T TEST SCORE
YEARS				
11-25 (n=8)	11	2.839 ***	2	1.025 *
4-10 (n=7)	14	3.959 ***	-1	-.439 *
0-3 (n=7)	16	3.183 ***	5	1.225 *

Note. *p>.05. ***p<.01.

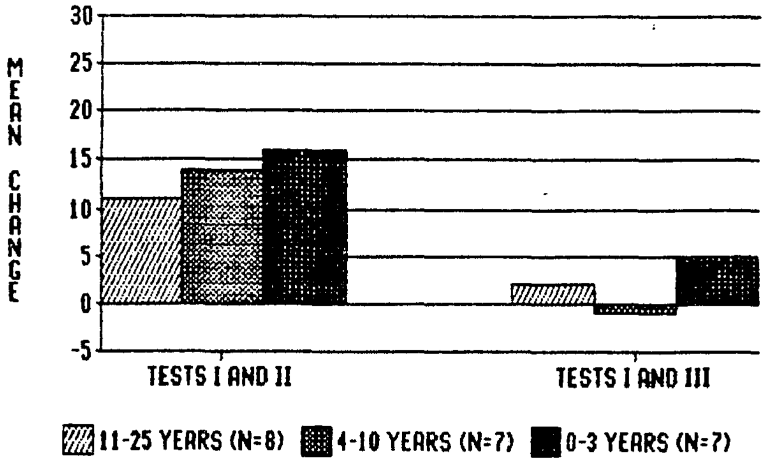

Figure 8. Mean Difference Between Tests as a Function of Years of Teaching Physics Experience

experience increased the most (5), but none of the t-test scores for increases in any of the three groups were significant.

Comparison of Percentage of Correct Responses to Conceptual Questions Versus Analytical Problems

Table 9 shows the mean scores of the conceptual questions and the analytical problems on each of the test batteries in each topic area. Figure 9 is a graphical representation of the fourth and eighth columns in the table which are the means of all three test batteries by topic area. The sixth row is the mean of each of the individual test batteries. The overall mean values for all the conceptual questions and the analytical problems are underlined in the sixth row. The overall mean score of the conceptual questions is 68 while the overall mean score of the analytical problems was only 37. This is a very significant difference. The *t*-test score was 14.003 which is significant at the .001 level.

Testing of the Hypotheses

The following relates the hypotheses to the data tables and graphs:

1. High school physics teachers who participate in the inservice program, "Teaching Physics Teachers with Technology," will have a statistically significant

Table 9

Mean Percentage Correct for Conceptual Questions and Analytical Problems

	CONCEPTUAL				ANALYTICAL			
TEST TOPIC	TEST I	TEST II	TEST III	MEAN BY TOPIC	TEST I	TEST II	TEST III	MEAN BY TOPIC
MECHANICS	55	71	56	61	25	33	29	29
MODERN	71	87	84	81	12	27	18	19
OPTICS	53	71	59	61	41	72	42	52
E & M	55	65	61	60	18	49	28	32
THERM	69	78	81	76	43	54	62	53
MEAN BY TEST	61	74	68	68	28	47	36	37

n = 251
T SCORE = 14.003
LEVEL OF SIGNIFICANCE = .001

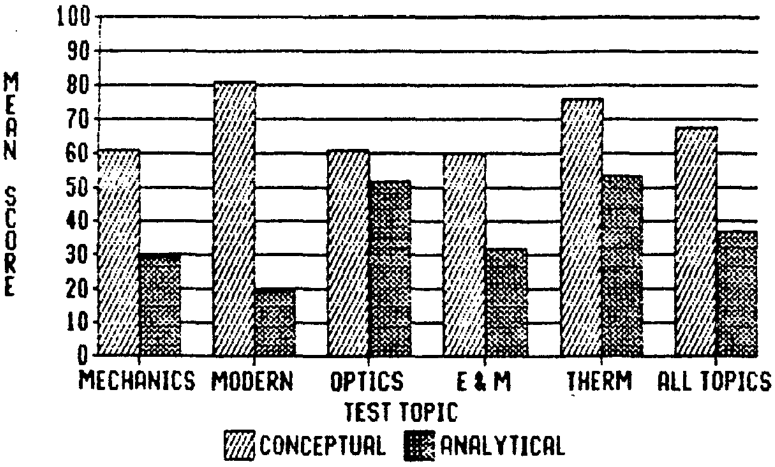

Figure 9. Mean Score of Conceptual Questions Versus Analytical Problems as a Function of Test Topic

increase in the content knowledge test scores between Tests I and II.

Table 2 indicates a significant increase in mean scores in all five topic areas. The conclusion is that teachers have had a significant short-term increase in content knowledge as a result of the inquiry workshop. Therefore, Hypothesis 1 was accepted.

2. High school physics teachers who participate in the inservice program will have a statistically significant increase in the content knowledge test scores between Tests I and III.

   Table 2 indicates that while there was an increase in mean scores between Tests I and III in three of the topic areas, none of the five areas showed a significant increase. The conclusion is that there was minimal long-term retention of the content knowledge for the group as a whole. Therefore, Hypothesis 2 was rejected.

3. Teachers' content test scores will improve significantly in content areas where participants developed and taught modules (PTM) in which the teaching objectives were similar to those objectives being tested in that particular content area.

   Table 4 shows that while both of the whole group's mean gains in thermal and electricity and magnetism were significant, neither of the parallel module group's increases in scores between Tests I and II were significant in part due to the very small sample size. Neither of the whole group gain scores were significant between Tests I and III. While both of the parallel module groups' gains were high between Tests I and III, neither of the increases were significant in part due to the small sample size. The conclusion is that the development and teaching of materials may enhance content knowledge gains and retention, but the evidence was inconclusive. Therefore, Hypothesis 3 was rejected.

4. Performance on Test Battery I will be higher for participants with physics degrees than for those participants who do not hold physics degrees. Table 5 and Figure 5 demonstrate that those groups with the highest level of physics academic preparation did score the highest on Test I. The mean of the participants with a major in physics was 58, those with a minor, 53; and those with less than 18 semester hours in physics, 46. It can be concluded that content knowledge does vary with level of academic preparation. Therefore, Hypothesis 4 was accepted.
5. The scores of participants with physics degrees will increase significantly more between Test Batteries I,

II, and III than the scores of teachers with less physics preparation.

Table 6 and Figure 6 show that while the increase between Test I and Test II was approximately the same (12 and 14) for all three groups, the level of significance was higher for the minimal preparation group than for the other two groups with those with a major having the least level of significance. Table 6 also shows that there was no significant gain for any of the three academic preparation groups. The conclusion is that there were significant short-term content knowledge gains for all three academic preparation groups, but there was no significant retention of the content knowledge for any of the three academic preparation groups. Therefore, Hypothesis 5 was rejected.

6. Performance on Test Battery I will be higher for participants with more physics teaching experience than for those participants with less physics teaching experience.

Table 7 and Figure 7 show that the group with the most years of experience scored highest on Test I (58), the mean score (53) of those with a moderate level of experience was in the middle, while those with only 0-3 years of experience scored the lowest (40) on Test I; thus it can be concluded that experience may enhance content knowledge. Therefore, Hypothesis 6 was accepted.

7. The scores of participants with more physics teaching experience will increase significantly more between Test Batteries I, II, and III than the scores of teachers with less physics teaching experience. Table 8 and Figure 8 show that while all three experience groups significantly increased their mean scores between Tests I and II, those with the least experience increased their scores more than those with more experience. None of the three groups had a significant gain between Tests I and III. Little can be concluded about the effect of years of experience on the participants' learning by inquiry instruction. Therefore, Hypothesis 7 was rejected.

8. There will be no significant difference between conceptual test scores and analytical test scores. Results shown in Table 9 show that the mean score of all the conceptual questions was 68 while the mean score of all the analytical problems was only 37. The sample size was large and the t-test score was 14.003. This difference was very significant. The scores tend to have the same relative increases and decreases between Tests I, II, and III; therefore, the conclusion is that the participants did significantly

more poorly on analytical problems than on conceptual questions. Therefore, Hypothesis 8 was rejected.

CHAPTER V

Observations and Conclusions

This study was designed to investigate the relationship between inquiry instruction and content knowledge gains due to that instruction. The results from the three content knowledge test batteries administered to the 22 North Carolina high school physics teachers who participated in the TPTT workshop were examined in several ways. These include initial pretest results and gains in content knowledge by topic areas, level of academic preparation, and number of years of physics teaching experience. Mean results on conceptual questions and analytical problems were compared to help in planning future workshops and content knowledge evaluation instruments for this particular group of teachers. The study also examined the performance of the participants who developed and used materials with objectives similar to the objectives tested in two of the topic areas and compared the means of these groups to the means of the whole group in each of the two topic areas.

The analysis of the data consisted of comparisons between the pretest and both the short-term and long-term posttests. To test for statistical significance between the pretests and each of the posttests, a one-tailed dependent _t_ test was used. This particular form of the _t_ test also required the use of the Pearson Product-Moment Correlation Coefficient.

Chapter IV included the hypotheses and the details of the data analysis. Chapter V will discuss the findings, conclusions, implications, and recommendations of this study.

Discussion of Findings

The discussion of findings will be presented under five headings. The first is a comparison of results by topic area, the second is a comparison of results of module development and use, the third is a comparison of results by level of academic preparation, the fourth is a comparison of results by number of years of physics teaching experience, and the fifth is a comparison of results on conceptual questions and analytical problems.

Since the sample size is small in many of the comparisons, content knowledge gains which are significant at less than or equal to the .05 level will be considered significant for the purposes of discussion.

Comparison of Results by Topic Area

The content area electricity and magnetism was the lowest initial mean score while thermodynamics had the highest initial mean score. Thermodynamics had the highest mean score on all three test batteries. Thermodynamics mean scores were 67, 75, and 78 on Tests I, II, and III, respectively. The Test I low mean score was 37 in electricity and magnetism. The Test II low mean score was 55 in mechanics. The Test III low mean score was 47 in both electricity and magnetism and mechanics. The mean score for Test Batteries I, II, and III was 51, 66, and 58, respectively. The largest increase in mean scores was 22 (between Tests I and II) and 5 (between Tests I and III) in electricity and magnetism, the topical area with the lowest initial mean score. The increase in scores between Tests I and II was significant for all five topic areas. There were no significant increases in scores in any of the five topic areas between Tests I and III.

All of the initial mean scores were in the middle range (30% to 70% correct), and this was to be expected for two reasons. These are topic areas in which the participants had a need for help, and the test instrument is designed with questions and problems with a wide range of difficulty. The initial scores to a large degree are indicative of the familiarity of the participants with the concepts taught in the minilessons. Capacitance (electricity and magnetism) may be a topic few participants teach, while heat transfer (thermodynamics) would be a very familiar topic. The fact that initial scores for thermodynamics were high may suggest a change in topics for future workshops. Since the test batteries measure very specific concepts in each topic area and not general knowledge, the mean scores in the areas measured tend to vary widely.

The fact that electricity and magnetism had the lowest initial mean score (37) may have been part of the reason it had the largest increase between Test I and the other two tests. There was more room for improvement in electricity and magnetism while thermodynamics results may have suffered from a ceiling effect. Both Test II and Test III scores would be influenced by statistical regression toward the mean. The low electricity and magnetism score would tend to increase toward the mean while the thermodynamics score would tend to decrease toward the mean.

Since all five topic areas showed a significant increase in scores between Tests I and II, this suggests that inquiry instruction can increase the content knowledge of the participants. The fact that there was no significant gain in any of the test areas between Tests I and III is supported by the literature. Miller (1978) stated that 80% of factual material "learned" is forgotten in the first six months.

The author also believes that some of the participants did not perform well on Test Battery III due in part to affective factors (i.e., fatigue, boredom with the process, etc.). This is supported by comments by the participants and the decreased amount of time the participants spent on Test Battery III as compared to Test Batteries I and II.

Comparison of Results of Module Development and Use

There were increases in all four scores for the two parallel module groups, but none of the gains between Tests I and II or Tests I and III were significant. This was in contrast to the significant increases in the total group's scores from Tests I to II, while none of the whole group's Tests I to III scores were significant.

Both Tests II and III gains were larger for the electricity and magnetism parallel module group (34 and 17, respectively) than for the total group (22 and 5, respectively). The total group's thermodynamics Test II gains (14) were greater than the thermodynamics module group's gain (12), but the total group's thermodynamics Test III gain (3) was lower than the module group's Test III gain (16). Thus the thermodynamics module group's Test III gains were larger than the total group's Test III gains and larger than the module group's own Test II gain.

The data leaves open the question of whether the parallel module development and teaching enhanced long-term learning. The electricity and magnetism mean score (17) for the module group was higher than any of the five whole-group increases and the thermal module group had the second largest gain (16). The largest mean increase between Tests I and III for the whole group was 5 in electricity and magnetism. While the module groups had large increases between Tests I and III these increases were not statistically significant in part due to the small sample size of the module groups (3 and 4).

The larger mean increases in scores for the parallel module groups might be expected in light of the time-on-task research (Blosser & Mayer, 1983). This research suggests a possible shift in direction for inservice procedures where high need in a specific topic area is experienced. Time-on-task research such as that done by Berliner suggests that teachers and workshop leaders can teach whatever they allocate class time to teach.

Comparison of Results by Academic Preparation

The performance of those with the equivalent to a major in physics surpassed the other two groups on Tests I and III, and those with the equivalent of a minor or at least 18 semester hours in physics performed better than those with less academic preparation on Tests I and III. All means were approximately equal for those who took the various parts of the Test II battery.

While the increases between Tests I and II were approximately equal for all three levels of academic preparation and all three gains were significant, the mean scores for those with minimum academic preparation had the most significant increase and the scores for those with a major in physics had the least significant increase.

While all three groups had a significant improvement between Tests I and II, those with minimum academic preparation made the most significant short-term gains between Test Battery I and Test Battery II. There were no significant increases in mean scores between Test Batteries I and III for any of the academic preparation groups.

As one would expect, those participants with a physics major achieved the highest mean score on Test I (58), those with a physics minor were in the middle with a mean score of 53, while those with the least physics academic preparation scored a 46. The fact that those with a major in physics made the least significant gain between Tests I and II was in part due to the fact that the level of significance is determined not only by the amount of change between scores but also by the number of scores being compared. As the sample size decreases the difference between scores must increase in order for the level of significance to remain at any particular level. Since the physics major group was the smallest of the three groups a larger increase in scores was required for their gains to be as significant as the other two groups. Those with a major also had the highest initial scores, therefore the ceiling effect was a limiting factor. Those with a minor had less significant gain than the minimum preparation group in part due to the same reasons as the physics major group.

There does not seem to be much information in the literature about these relationships other than studies such as those conducted by Carey and Stauss (Cited by Billeh & Hasan, 1975) who investigated the relationship between science teachers' understanding of science and college science credit hours. They found that a significant increase in the teachers' understanding of science occurred as a result of completing a science education course.

Comparison of Results by Years of Physics Teaching Experience

Those with larger amounts of experience tended to do better on each of the three test batteries. In order of most experience to least experience for Test Battery I, the mean scores were 58, 53, and 40; Test Battery II, 69, 66, and 60; and Test Battery III, 63, 57, and 52. Those with the least experience had the greatest increase for Tests II and III, and all three groups' increases in performance between Tests I and II were significant. Those with 0-3 years' experience mean scores increased by 16 while those with 4-10 and 11-25 years' experience increased by 14 and

11 respectively. None of the increases between Tests I and III for any of the three groups were significant.

The data on Test I showed that those participants with the most experience scored higher than the other two groups while those with the least experience scored lower than the other two groups. All groups had significant increases between Tests I and II with the less experienced group having the largest increase in mean scores and those with the most experience having the smallest increase in part due to the ceiling effect. None of the experience groups had a significant increase in mean scores between Tests I and III.

The literature is not clear in this area. George and Nelson (1971) found that in their inservice program younger teachers were more likely to get high scores on content tests. "There are very few investigations that address themselves to age and/or years of experience and success in inservice work; and those that do, give inconsistent results" (Butts, 1981, p. 415).

Comparison of Results of Conceptual Questions Versus Analytical Problems

Because the evaluation instrument is a key to the pilot study, there are questions which should be asked about it. One of those is how performance on different types of test questions compared. The overall mean score on the conceptual questions was 68, while the overall mean score on the analytical problems was only 37. This was a very significant difference.

These results suggest several considerations for the evaluation instrument. They may also suggest a shift of emphasis in future workshops. If the large difference in scores was due to a participant preference for multiple-choice questions over analytical word problems, it could be argued that the analytical problems were counted correct even with one or two small calculation errors. Many of these same common errors could have easily been among the choices in a multiple-choice question. If this were the case, when participants made a "common error" in a calculation, they would select an answer which would be counted completely wrong. Possibly participants did not want to take the time to do the calculations in the later test batteries, but the same pattern existed in Test I results alone. The participants may have improved their analytical scores if equations had been given, but all constants were given and the numerical quantities in the problems included units. Therefore, participants could have used the problem-solving strategy of working the problem through using the units.

The evidence is not clear but a possibility exists that future workshops should concentrate more on the area of analytical problem solving. Future evaluation instruments should include equations and only multiple-choice questions to eliminate the influence of these two factors. More research should be done in this area.

Two reasons for low scores on the analytical problem-solving portion of the tests may have been a lack of academic preparation and experience. Future studies should break the results down in these two areas to investigate the relationships of these variables to analytical problem-solving ability. Of the TPTT group approximately one third had minimum physics teaching experience and almost half had minimum academic preparation.

Observations and Conclusions

The central purpose of this study was to determine to what extent inquiry instruction increased the content knowledge test scores of 22 high school physics teachers on short- and long-term evaluations. Little research is available of this type. While some research has been done in the area of content knowledge gains as a result of inquiry instruction, most of the inquiry research was in the areas of process and attitudinal changes. Even though no information was found specifically concerning research on inservice inquiry instruction with content evaluation for high school physics teachers, in general, results of this study were in agreement with the literature.

There is a concern that while most teachers believe in inquiry instruction, most do not implement it to any extent. Two of the major reasons for this seem to be lack of appropriate models and a concern that inquiry instruction will not teach the content needed to move to the next level of instruction. The TPTT workshop modeled inquiry instruction and the evaluation measured content gains by the participants as a result of the inquiry instruction. The results of the evaluation will be useful in helping plan the two future TPTT workshops and other future inservice programs for various subgroups (e.g., minimum experience and academic preparation) of high school physics teachers.

While the study is useful, there are several drawbacks. Three main concerns include the small size of the sample, the ceiling effect for those with initial high scores, and the attrition and fatigue factors.

The original group was small to begin with (22), but 4 participants dropped out of the program before its conclusion. This simply made it more difficult to measure significant gain between various combinations of mean test scores. This was particularly true with respect to measuring gain with the two parallel module groups. Part of this problem can be eliminated by using the same evaluation instrument in the workshop each year and combining the results over several workshops.

The second factor to consider when viewing the results is the ceiling effect in scoring the individual tests. If a participant scores 100 on one of the tests on Test Battery I, while that same score will be continued or drop on Tests II and III, the participant cannot "pull up" the mean for that group on either of the succeeding tests in that topic area. This reduces the increase possible between tests and thus will cause some loss in significance when there should not be any loss. The possible effect of this factor will tend to increase as the sample size (n) decreases.

The fatigue factor seemed to take effect during the administration of Test Battery III, and the instructors, workshop director, and evaluator heard comments and noticed a general desire by some of participants not to put much effort into the third set of tests. The evaluator observed that most of the participants spent 40-50 minutes on Test Battery I during the first 1-hour session, and the longest time spent during this session was just over 1 hour. In contrast some "finished" the same section of Test Battery III in approximately 10 minutes, most in 25-30 minutes, and the longest in just over 40 minutes.

Based on the data and limited to the participants studied, the following conclusions were made:

1. There was definitely a content knowledge short-term gain as a result of the inquiry instruction in all topics studied. While there was some increase in long-term scores in three of the five areas studied, no significant gains were made in any area. The reasons for this are unclear. There may have been little retention over the 3-month period between tests I and III and/or there may have been other affective reasons for no significant change in scores over this longer period. It was the evaluator's belief after studying video tapes of the workshop and analyzing the data from the content evaluation that the workshop was successful in teaching content knowledge while modeling inquiry instruction.
2. The results from Test Battery I suggest that there were content areas in which participants did indeed need more attention, such as electricity and magnetism or more specifically, capacitors.
3. The sample size was small for the parallel module groups, and none of the gains were statistically significant. However, there was some evidence that continuing to work with inquiry materials in a given content area did improve content knowledge gains in that area. This might imply that future workshops should focus more inservice attention to weak content areas.

4. While experience was not a factor, there was evidence that academic preparation did affect what was learned and the amount of content participants could learn and retain. Future workshops might be divided such that participants are grouped in two categories, those with at least a minor in physics and those with less than 18 semester hours in physics.
5. Future evaluation instruments should emphasize multiple-choice questions and provide any needed equations given on the test. This will help determine whether future workshops should provide more emphasis on analytical problem solving. The results should also be broken down by experience and academic preparation groups to determine in which groups to emphasize which skills.

Implications and Recommendations

As a pilot study in a group of three studies of TPTT workshops, this initial study offers insights into several areas. While the workshop itself offers a good inquiry inservice model, the study adds to the evidence that content knowledge does not have to be sacrificed for inquiry instruction. Based on the findings and conclusions of this study and the review of the literature, the following are recommendations for future study.

A follow-up observational study should be conducted to determine how much of what was learned in the workshop is used when the participants teach their classes. Also, a study should be conducted with an equivalent control group using a lecture format which "covers" the same minilesson objectives during the same period of time. This level of commitment would probably have to occur at the national level and could be done in connection with the national AAPT summer meetings.

Retention of content by participating teachers was a problem in both this study and others cited in the literature (Miller, 1978). The author believes that this implies at least two things: Inservice must continue to improve, and research must continue to determine what factors enhance retention. Further research may suggest that inservice must be continuous, and the content knowledge must be reinforced periodically or not be retained.

One of the relatively clear implications from the study is for inservice planners to be sensitive to the workshop participants' academic preparation. This "sensitivity" can take several forms. One of the most obvious is to have different workshops, one for teachers with at least a minor in physics and another for teachers (many of whom have been "drafted" into teaching physics) with less than 18 semester hours in physics. Another strategy to deal with the differences in teachers' physics preparation might be to group the participants by level of academic preparation within a workshop, or let those with a higher level of academic preparation take more of the leadership of the group. A "buddy system" might also be used with a participant with a good physics academic background (and/or physics teaching experience) being teamed with one or two participants with weaker physics backgrounds. This gives the weaker participant more individualized attention and provides reinforcement for the tutor. Future content knowledge research should include an analysis of the data grouped by academic preparation. The data could be collected for a series of similar workshops using the same teaching objectives and the same evaluation instrument to do more in-depth research with a larger sample size.

There is an indication that developing and continuing to work with a set of hands-on materials enhances content knowledge gains. This supports the time-on-task philosophy (Blosser & Mayer, 1983). One implication of this strategy is to apply it to topic areas in which the content knowledge is most needed by the participants. Additional studies should be conducted to determine how much of an effect this might have on content retention. To determine what content areas need the most attention, a broad standardized test should be given to future workshop participants (once again being sensitive to academic background when interpreting the results). This information could then be used not to plan a "snapshot" workshop, but a series of workshops for a particular group of physics teachers with similar academic backgrounds who are weak in specific topic areas.

Evaluation is another area in which improvements can be made. The first is for future TPTT workshop content evaluation instruments to contain all multiple-choice questions and problems with all equations needed on the tests to be given on the tests. This would reduce the effect of any intervening variables which might be contributing to the low results on the analytical problem solving. If the tendency to do poorly on analytical problem solving continues, future inservice efforts should be directed toward teaching problem-solving approaches and strategies. A second recommendation concerning evaluation is to develop a set of content evaluation instruments and to establish their reliability.

In this study the evaluator did not see any increase in scores due to familiarity with the instrument. This was one factor considered when the decision was made to give only part of the tests to each participant during the administraton of Test Battery II at the end of the summer workshop. Therefore, future evaluations should be enhanced by giving all five topical tests at all three testing sessions.

The fatigue factor could be reduced by pretesting and posttesting in shorter sessions just before and after each minilesson. A 20- to 30-minute time limit could be set for each testing session. Participants must be made aware that the evaluation process is used to determine how to improve the effectiveness of the workshop. There needs to be some incentive developed to motivate and encourage the participants to do as well as they can on each of the evaluation instruments administered. This could take many forms and should be left up to the discretion of the workshop director.

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APPENDIX A

MINILESSON OBJECTIVES

Minilesson Objectives

Electricity and Magnetism

The student will be able to :

1. Describe a capacitor with a diagram showing field lines, +q and -q, and explain the concept of potential difference.
2. Use the relationship $q = CV$ to calculate capacitance, charge on the plates, and potential between the plates.
3. Describe the geometric parameters that affect capacitance such as area of the plates, distance of separation, and choice of a dielectric.
4. Derive the equations for capacitors in both series and parallel and use these to simplify circuits.

Thermodynamics

The student will be able to:

1. List the measurable variables which affect thermal energy transfer.
2. Write an equation for and explain the mathematical relationship between heat, mass, specific heat, and change in temperature.
3. Define heat energy, thermal energy, calorie, specific heat capacity, and calorimeter.
4. Calculate heat, mass, specific heat, or change in temperature given three of the variables.
5. Explain the relationship shown in a heat versus mass (of greenhouse slab) and heat versus temperature change plots.
6. Solve simple heating and cooling problems.
7. Explain why the law of conservation of energy applies to calorimetry problems.

Reflection and Refraction

Objectives to be learned from the laboratory:

1. When light is reflected, the angle of reflection equals the angle of incidence.
2. Generally, when light passes from a less dense substance to a more dense substance, the light bends toward the normal.
3. Generally, when light passes from a more dense substance to a less dense substance, the light bends away from the normal.
4. When the incident angle increases, the intensity of the reflected light increases.
5. When the incident angle increases, the intensity of the refracted light decreases.
6. The average speed of light decreases when light passes from a less dense medium to a more dense medium.
7. The angles of incidence and refraction for a specific frequency of light and two media are related and can be described using Snell's Law:

   $$\sin i = n * \sin r$$

   where n = refractive index

8. For light passing from one medium to another in which its velocity is greater (so that $n<1$) we may, for a large angle of incidence, encounter total reflection.
9. Light will be refracted very little as it passes through two fluids with similar absolute indices of refraction.
10. Viscosity of fluids have little effect on the magnitude of the refracted angle.

Radioactivity

The student will be able to:

1. Define radioactive decay, half-life, decay constant, alpha, beta, and gamma rays, source activity, absorbed dose, and biologically equivalent dose.

2. Sketch a graph of N (the number of nuclei) versus t (the time) for a radioactive substance.

3. Use the graph to determine the half-life.

4. Calculate the fraction of the substance that has not decayed after a certain interval of time using the equation

$$N = N_o e^{-\lambda t}.$$

5. State the relation between the decay constant and the half-life.

6. Define each variable in the equation $\Delta N = -\lambda N \Delta t$ and use the equation in simple situations.

7. Compare the range and ionization effect of alpha, beta, and gamma radiation passing through matter.

8. State what quantities are conserved in a nuclear reaction.

9. Write the nuclear equation (using the conservation laws) for a given nucleus that emits an alpha particle, beta particle, or gamma ray.

10. Sketch the radioactive series for a nucleus, given the starting nucleus and the emitted particles or rays.

11. Explain how carbon 14 is used in dating the age of objects.

12. Compute the age of a certain material, given the half-life of carbon 14 and the ratio N/N_o.

13. Explain the medical uses of radioactivity.

14. Compute the dosage needed in radio therapy given the time of exposure and the strength of the dosage.

Mechanics

The student will be able to:

1. Calculate the period of rotation, the centripetal acceleration, and the centripetal force, given the frequency and mass of a body in a circular orbit of known radius.
2. Define and give examples of fictitious forces, inertial and non-inertial frames of reference.
3. Derive the expression for the period of a conical pendulum.
4. Define escape velocity and geosynchronous orbit.
5. Calculate the period or orbiting distance of a satellite give the other variable.

APPENDIX B

GUIDELINES FOR DEVELOPING PHYSICS TEACHING MODULE

DEVELOPING MODULES FOR INSTRUCTION -- GUIDELINES

"We overestimate the ability of our students to learn from lectures and underestimate the ability of our students to think for themselves."

from: "Module Based Instruction in a
Community College Classroom," R. Green
and M. Nelson, Announcer Vol. 18 (2), 1988.

Research in the area of instructional strategies has demonstrated the shortcomings of the lecture method in fostering active learning on the part of the student. One of the goals of the Teaching Physics with Technology project is to provide time for teachers to develop lessons that rely less on lecture and more on instructional strategies that involve the student directly in learning.

Modules of instruction are one way to begin to change teaching strategies. Strategies that encourage the student to be active in learning are such strategies as lab, demonstration (with student participation), individualized instruction, research projects, and resource learning (i.e. involving written, video and audio material).

As you plan your module, use the grid below as a checklist for how you plan to teach the concepts.

INSTRUCTIONAL STRATEGY

CONCEPT	LAB	DEMO	INDIVIDUALIZED INSTRUCTION	RESEARCH & DEVELOPMENT	RESOURCE LEARNING	LECTURE

Your role as a teacher is one of motivator and facilator while the lesson is in progress. Your expertise is exploited in the planning of the lesson and bringing lessons to closure with thorough summaries. You as the teacher must relinquish your role as "fountain of knowledge" and develop the skill of asking probing questions.

Remember: We view teaching modules as vehicles of collaboration between physics teachers in high schools and physics teachers in college. The modules are a formal way in which we can interact as colleagues, a way for you to improve your teaching and a way for students to become actively involved in learning.

APPENDIX C

TEST BATTERIES

THERMODYNAMICS: Thermal Physics

Directions - All multiple choice questions may have more than one correct answer in the group list. Please circle all correct answers.

1. Heat is

   a. qualitatively the same as temperature
   b. the energy which flows from a hot body to a cold body when they are placed in contact
   c. total molecular kinetic energy of an object
   d. average molecular kinetic energy of an object
   e. none of the above

2. The temperature of a material is a measure of its

   a. total molecular kinetic energy
   b. average molecular kinetic energy
   c. thermal energy
   d. potential energy
   e. radiation

3. If you wanted to know how much heat was supplied to a metal cylinder when its temperature is increased by a certain amount, which of the following would be most helpful to know?

   a. mass
   b. density
   c. thermal conductivity
   d. coefficient of linear expansion
   e. specific heat

4. A piece of copper and a container of water both have the same mass and temperature. If they are heated so the thermal energy of each doubles,

   a. the water will have the higher temperature
   b. the copper will have the higher temperature
   c. both will have the same temperature
   d. we need to know the volume of each to determine which is warmer
   e. we need to know the initial temperature of each to determine which is warmer

5. The fact that the desert is so cool on a summer night is evidence that sand has a

   a. low specific heat
   b. high specific heat
   c. specific heat is not a factor
   d. sand is not a factor in the desert's temperature
   e. low entropy

6. How does the amount of thermal energy in 200 kg of water at 30°C compare to 500 kg of water at 30°C?

   a. the 200 kg has more thermal energy than the 500 kg
   b. the 200 kg has less thermal energy than the 500 kg
   c. the 500 kg has more thermal energy than the 200 kg
   d. we need to know the initial temperature of each
   e. they are equal

7. When 70 g of iron at 90°C is added to the same mass of water at 30°C, the resulting temperature of the mixture will be

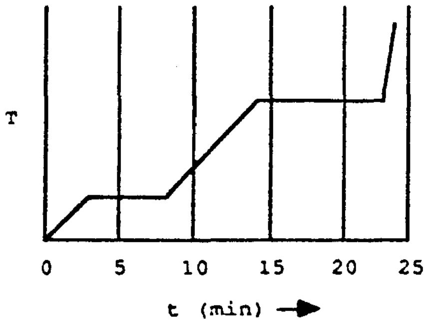
   a. between 30°C and 60°C
   b. 60°C
   c. between 60°C and 90°C
   d. 120°C
   e. none of the above

8. Aluminum has a specific heat greater than that of copper. Blocks of copper and aluminum, both of the same mass and both at 10°C, are placed in two different but identical calorimeters. Each calorimeter is filled with 200 g of water at 80°C. After equilibrium is reached,

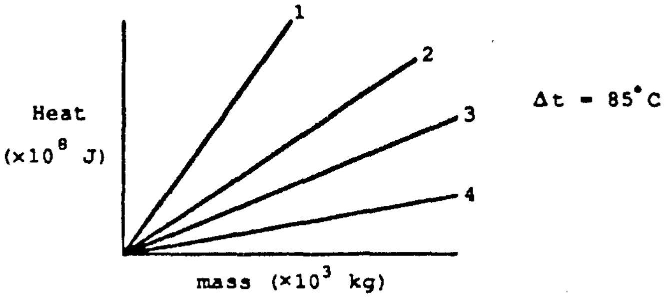
   a. the copper has a higher temperature than the aluminum
   b. the aluminum has a higher temperature than the copper
   c. the temperature of the two calorimeters are the same
   d. which is warmer depends on the volume of the two metal blocks since aluminum is much less dense than copper
   e. which is warmer depends on the specific heat and mass of the calorimeter cups

9. A compound is contained in a well-insulated container. Heat is added at a constant rate and the sample temperature is recorded. The resulting data is sketched below. Which of the following conclusions is justified from the data given?

   a. The sample was initially a mixture of solid and liquid
   b. After 5 minutes the sample was a mixture of solid and liquid
   c. The sample never boiled
   d. After 10 minutes the sample was a mixture of liquid and gas
   e. After 20 minutes the sample was all liquid



10. For several substances, the thermal energy absorbed by the substance while being heated is recorded, producing the following graph:



Which substance has the largest specific heat capacity?

a. substance 1 because it has the greatest slope
b. substance 4 because it has the least slope
c. substance 1 because larger amounts of thermal energy are absorbed per kg of mass
d. substance 2 because it has a constant ratio
e. substance 3 because it shows greater temperature change

11. Define a calorie.

12. Define a nutritionist's calorie.

13. In SI units, specific heat capacity, *c*, is measured in ____________.

14. A 2 L glass container has a mass of 0.3 kg when empty. If this container contains a 1.5 L of water at 20°C, how much heat must be supplied in order to raise the temperature of the water and container to 30°C? Assume that the specific heat of glass is 0.18 cal/g · C°.

15. A 70 g metal sample is submerged in boiling water until thermal equilibrium has been attained. The sample is then quickly placed in a 40 g copper calorimeter cup (c_{Cu} = .094 cal/g · C°) with 90 g of water at 10°C. After thermal equilibrium has been reached, the temperature of the water is 32°C. What is the specific heat of the metal?

16. A 50 g aluminum calorimeter (c_{Al} = .210) contains water at a temperature of 20°C. When a 120 g copper cylinder (c_{Cu} = .094) at 90°C is dropped into the calorimeter, the final equilibrium temperature is 34°C. How much water was in the calorimeter cup?

17. If we isolate part of a solar home-heating system, no energy is added or lost from the system as water circulates through an insulated concrete slab. Using the data below, find the equilibrium temperature of the water and slab.

substance	specific heat	mass	initial temperature
concrete	800 J/kg · C°	690 kg	20°C
water	360 J/kg · C°	360 kg	34°C

ELECTRICITY AND MAGNETISM: Capacitors

Directions - All multiple choice questions may have more than one correct answer in the group list. Please circle all correct answers.
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

1. A _______ is a device which is capable of storing electric charge.

   a. resistor
   b. diode
   c. capacitor
   d. conductor
   e. none of these

2. The capacitance of a parallel-plate capacitor is

   a. proportional to the area of the plates and the distance between the plates
   b. proportional to the area of the plates and inversely proportional to the distance between the plates
   c. proportional to the distance between the plates and inversely proportional to the area of the plates
   d. inversely proportional to the distance between the plates and inversely proportional to the area of the plates
   e. none of the above

3. Which of the following is (are) always true about a capacitor when it is connected to a battery?

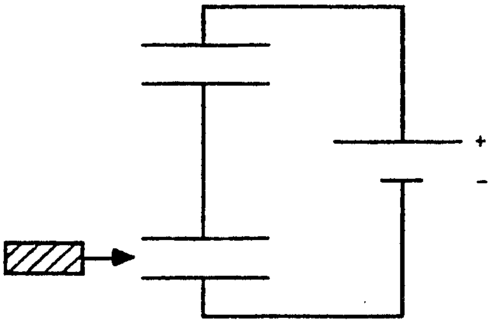
   a. Each plate will receive equal amounts of charge only if they have the same area
   b. If the distance between the plates is increased the area of the plates must also be increased in order to keep the capacitance constant
   c. Decreasing the area of plates will increase the electric field lines between the plates
   d. Increasing the distance between the plates will increase the amount of charge on the plates
   e. None of the above

4. A parallel plate capacitor is connected to a battery that has a constant terminal voltage. If the capacitor plates are pulled apart,

   a. the electric field decreases and the charge on the plates also decreases
   b. the electric field remains constant but the charge on the plates decreases
   c. the electric field remains constant but the charge on the plates increases
   d. the electric field increases but the charge on the plate decreases
   e. none of the above

5. In the diagram to the right both capacitors are identical and the battery maintains a constant voltage. When a dielectric slab is inserted into the lower capacitor,

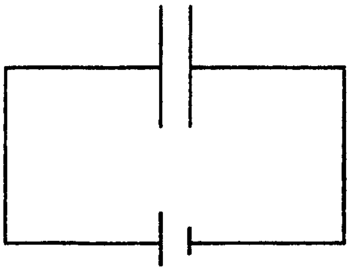
   a. the charge on the upper capacitor will increase
   b. The charge on the upper capacitor will decrease
   c. the potential difference across the lower capacitor will increase
   d. the potential difference across the lower capacitor will decrease
   e. the potential difference across the lower capacitor will remain unchanged



6. Two unequal capacitors are connected in series across a battery. Which of the following is true?

   a. The potential difference across each is the same
   b. The potential difference across the larger capacitor is greater
   c. The charge on each is the same
   d. The charge is greater on the smaller capacitor
   e. The equivalent capacitance is the sum of the two capacitances

7. Label the capacitor diagram below showing the field lines, and where +q and -q are located.



8. Derive the equation for the equivalent capacitance of three capacitors connected in parallel.

9. Derive the equation for the equivalent capacitance of three capacitors connected in series.

10. What is the correct expression for the potential difference across a capacitor.

11. What is the unit of capacitance?

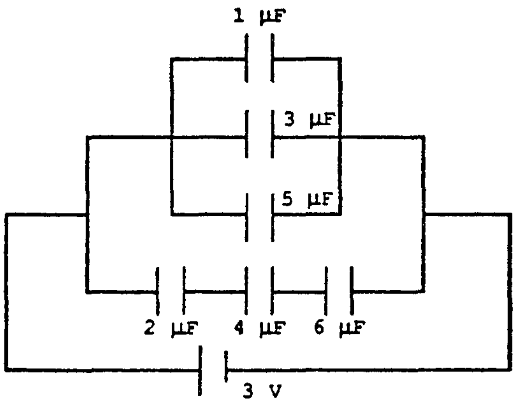
12. A parallel plate air capacitor has a plate area of 400 cm^2 and a separation of 0.3 mm. What is its capacitance?

13. When an uncharged 8.0-μF capacitor is connected to a 12-V battery. How much charge is drawn from the battery?

14. When 1200 μC is transferred from one plate of an uncharged capacitor to the other, the voltage across the capacitor becomes 40V. Calculate the capacitance of the capacitor.

15. A parallel-plate air capacitor has 0.3 μC of charge when a potential difference of 500 V is across its plates. The gap between the plates is 0.4 mm. Find the area of the plates and the capacitance of the capacitor.

16. Six capacitors are connected as shown below. Find the equivalent capacitance of the network, the potential difference across each capacitor, and the charge on each capacitor.



17. An 8 μF capacitor and a 2 μF capacitor are connected in series to a 12-volt battery. A material of dielectric constant 4 is inserted in the 2 μF capacitor. Calculate the charge on and potential difference across each capacitor before and after insertion of the dielectric.

MODERN PHYSICS: Radioactivity

Directions - All multiple choice questions may have more than one correct answer in the group list. Please circle all correct answers.

1. An alpha particle is

   a. an electron emitted by a nucleus
   b. a proton emitted by a nucleus
   c. a neutron emitted by a nucleus
   d. a photon emitted by a nucleus
   e. none of these

2. When thorium emits a beta particle the resulting nucleus has an atomic number (compared to that of thorium)

   a. decreased by 2
   b. decreased by 1
   c. unchanged
   d. increased by 1
   e. increased by 2

3. The "half-life" of a radioactive sample is the time for which

   a. 37% of the original number of radioactive nuclei will be present
   b. 63% of the original number of radioactive nuclei will be present
   c. the number of radioactive nuclei will have decayed to half their original number
   d. the level of radioactivity (in counts per minute) will have decayed to half its original number
   e. none of the above

4. In the nuclear reaction ${}^{239}_{93}\mathrm{Np} \rightarrow {}^{239}_{94}\mathrm{Pu} + x$, the particle x is

   a. a neutron
   b. an electron
   c. a proton
   d. an alpha particle
   f. a positron

5. Which of the following nuclear reactions is (are) possible?

   a. ${}^{12}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{12}_{6}\mathrm{C} + \beta^{+}$
   d. ${}^{214}_{82}\mathrm{Pb} \rightarrow {}^{0}_{1}e + {}^{214}_{83}\mathrm{Bi} + \bar{\gamma}$
   b. ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\alpha \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$
   e. ${}^{107}_{48}\mathrm{Cd} + {}^{0}_{-1}e \rightarrow {}^{106}_{47}\mathrm{Ag}$
   c. ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} + {}^{1}_{0}n + {}^{1}_{0}n$

6. A radioactive source registers 128,000 counts per second. Eight-hours later, the counter registers 8000 counts per second. It follows that the half-life of the isotope is

   a. 1.5 min
   b. 3 min
   c. 6 min
   d. 8 min
   e. none of the above

7. Which of these quantities are conserved in a nuclear reaction?

   a. energy
   b. velocity
   c. momentum
   d. charge
   e. all of the above
   f. none of the above

8. The thorium series starts with $^{232}_{90}Th$ and emits in succession one α, two β, four α, one β, one α and one β particle(s). The final product of the series is

   a. $^{209}_{83}Bi$

   b. $^{208}_{82}Pb$

   c. $^{226}_{88}Ra$

   d. $^{208}_{86}Rn$

9. When a $^{238}_{92}U$ nucleus emits an alpha particle, the resulting nucleus has atomic number

   a. 90
   b. 91
   c. 92
   d. 93
   e. 94

10. Some rock fragments were analyzed and were found to have rubidium-80 and strontium-80 present in the ratio 9:1 (rubidium is the larger quantity present). It is known that rubidium-80 decays radioactively to the stable isotope strontium-80 with a half-life of 4.7×10^{10} years. If we assume the rock was initially 100% rubidium-80, what would be the age of the rock?

11. A radioactive sample is monitored over a 31-hour period. The data obtained is given here. Draw the exponential decay curve for this sample on the graph sheet provided. Use the graph to determine the half life of this sample.

Time (hrs.)	Count/min
0	7020
3	6400
9	5320
26	3200
31	2660

12. For the sample in question 11 above, what would you expect the radioactivity (in counts per minute) to be 62 hours after the beginning?

13. Explain how carbon 14 is used in dating objects.

OPTICS: Reflection and Refraction

Directions - All multiple choice questions may have more than one correct answer in the group list. Please circle all correct answers.

1. Light reflects off of an optically smooth transparent substance. Compared to the angle of incidence, the angle of reflection is

   a. the same
   b. larger
   c. smaller
   d. not enough information given
   e. false statement - light passes through transparent objects

2. Light passes from one optically smooth transparent substance to another. Compared to the angle of incidence, the angle of refraction is

   a. the same
   b. larger
   c. smaller
   d. bent toward the normal
   e. not enough information given

3. As the incident angle increases, the intensity of the reflected light

   a. increases and the intensity of the refracted light increases
   b. decreases and the intensity of the refracted light decreases
   c. increases and the intensity of the refracted light decreases
   d. decreases and the intensity of the refracted light increases
   e. and of the refracted light remain the same

4. When light passes from a less optically dense medium to a more optically dense medium, the average speed for the light

   a. increases and the frequency decreases
   b. decreases and the frequency increases
   c. increases and the wavelength decreases
   d. decreases and the wavelength increases
   e. decreases and the wavelength decreases

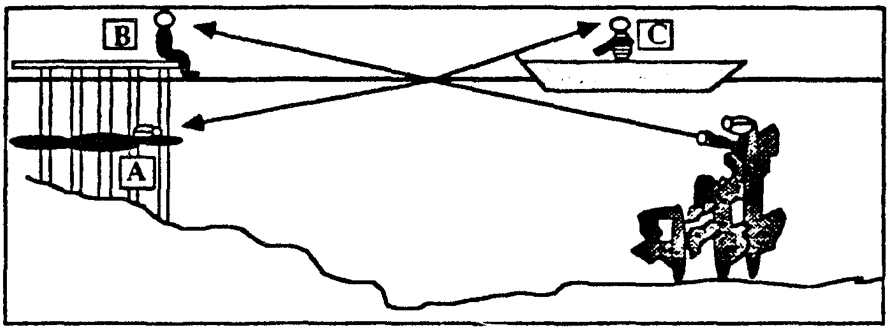
5. Light refracts as it passes from one transparent medium to another. Snell's law states that the ratio of sin i to sin r is

   a. greater than 1
   b. constant for a specific frequency
   c. constant for any frequency
   d. equal to the refractive index of the second medium
   e. equal to the refractive index of the first medium

6. Light travels from a transparent substance (refractive index = 1.52) to a second transparent substance (n = 1.0). Using an alternative form of Snell's Law, $n_1 \sin i = n_2 \sin r$, what incident angle would produce a refracted ray at 90°?

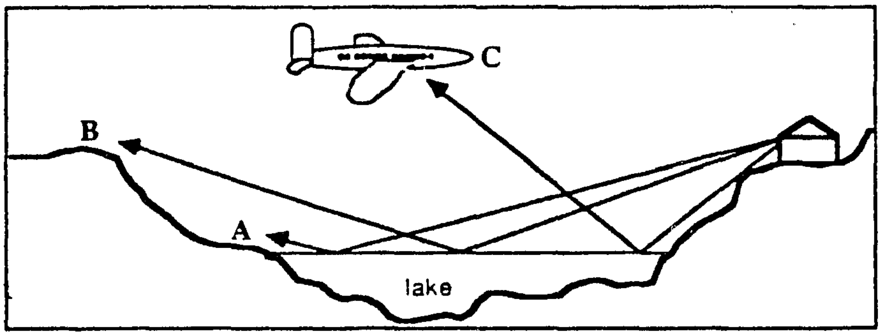
   a. 31°
   b. 41°
   c. 45°
   d. 60°
   e. the refracted ray could never be at 90°

7. A scuba diver is caught in the weeds at the bottom of a clear lake. She signals for help with a light which has a bright beam. Which person is more likely to see the light?



a. The other scuba diver
b. The person on the dock
c. The person in the boat
d. All three will see the light equally
e. None, the light will take another path

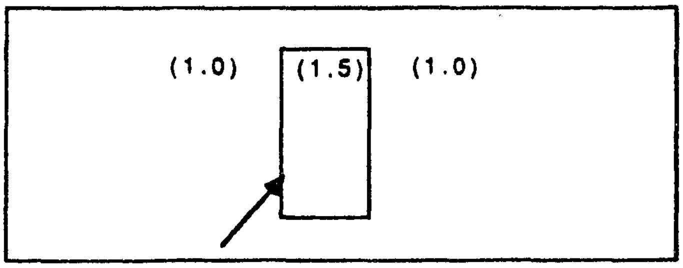
8. A person can see the house reflected best in the calm, clear mountain lake at which position?



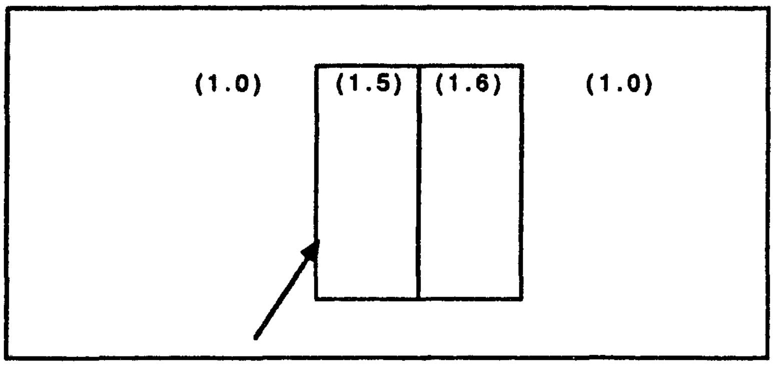
a. Position A
b. Position B
c. Position C
d. All three positions
e. There will be no reflection

Diagrams

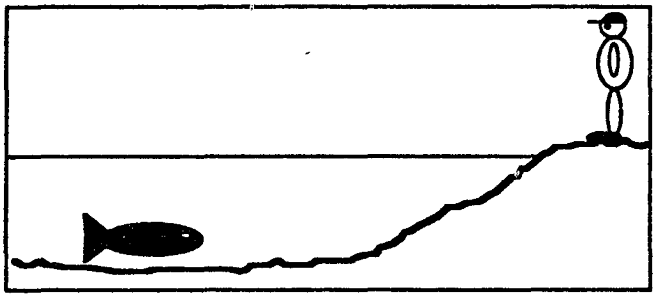
9. Sketch the refracted and reflected rays in the media (refractive indices in parentheses). Pay particular attention to the magnitude and direction of the bends.



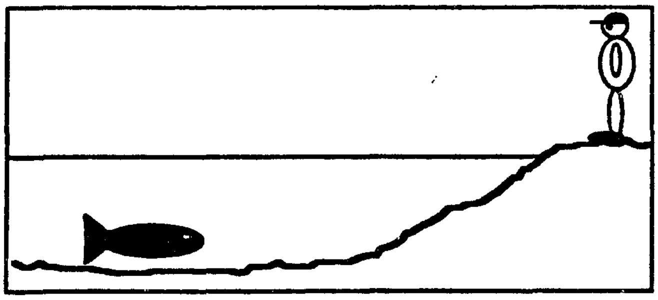
10. Sketch the refracted rays in the media (refractive indices in parentheses). Pay particular attention to the magnitude and direction of the bends.



11. A fish looks at a person on the shore of a clear, calm lake. Draw the ray of light from the person's hat to the fish's eye.



12. A person looks at a fish from the shore of a clear, calm lake. Draw the ray of light from the fish's head to the person's eye.



Problems

13. Yellow light (589 nm) travels from air ($n_{air} = 1.0$) into glass ($n_{glass} = 1.5$) at an incident angle of 60°. What is the refracted angle?

14. The average speed of blue light upon entering a substance at an incident angle of 30° decreases by 20%. What is the refracted angle?

MECHANICS: Circular Motion

Directions - All multiple choice questions may have more than one correct answer in the group list. Please circle all correct answers.

1. The speedometer on a car is calibrated with regular highway tires. What effect will replacing the regular tires with thick-tread snow tires have on the speedometer reading?
    a. this would cause the speedometer to read higher than its true highway speed
    b. this would cause the speedometer to read lower than its true highway speed
    c. this would have no effect on the accuracy of the reading since the speedometer is calibrated for a given angular velocity
    d. this would have no effect on the accuracy of the reading since the speedometer measures linear velocity not angular velocity
    e. this would have no effect on the accuracy of the reading, but for none of the reasons listed above
2. "Centrifugal forces" are a "reality" to observers in a reference frame which is
    a. at rest
    b. moving at constant velocity
    c. an inertial reference frame
    d. a non-inertial reference frame
    e. none of these
3. Suppose you are riding on a merry-go-round at some distance from the center. As you move in toward the center of the merry-go-round, the centripetal force you would experience would
    a. increase
    b. be unchanged
    c. decrease
    d. be zero
4. Some communication satellites have geosynchronous orbits because
    a. they are beyond the pull of the Earth's gravitational field
    b. they are stationary in space
    c. they have orbital periods of 24 hours
    d. they are moving at a speed slightly greater than the escape velocity
    e. none of these
5. A satellite near the Earth has an orbital period of about two hours. What would be its orbital period around the earth if it were located as far away as the Moon?
    a. about two hours
    b. about 24 hours
    c. between 2 hours and 14 days
    d. about 28 days
    e. it depends on the mass of the satellite

6. The slowest moving planet in the solar system is

   a. the planet nearest the sun
   b. the planet farthest from the sun
   c. the smallest planet
   d. the most massive planet
   e. none of the above

7. Define escape velocity.

8. The radius of the earth is approximately 6380 km. How fast is a person standing on the equator moving due to the rotation of the earth?

9. A centrifuge has an effective radius of 4 cm and rotates at 1,000 RPM. What is the centripetal acceleration of a sample placed in the centrifuge?

10. During the lunar mission of Apollo 11, the command module remained in orbit for a period of 2 hours and 20 minutes. How high above the moon's surface did it orbit?
    Given: $GM_{moon} = 5 \times 10^{12}$ N-m^2/kg
    $R_{moon} = 1.7 \times 10^6$ m

11. What is the centripetal acceleration of a point on the rim of a flywheel 0.60 m in diameter, turning at the rate of 1900 rev/min?

12. The moon revolves around the earth about once every 28 days, its average distance from the earth is 3.84×10^8 m and it has a mass of 7.4×10^{22} kg. The earth's radius is 6.38×10^6 m. Assuming that the moon moves in circular orbit about the earth, calculate its centripetal acceleration and the centripetal force the earth exerts on it.

13. In the derivation of the period of a conical pendulum, what is the net force on the pendulum bob? The pendulum makes an angle θ with the vertical, T is the tension in the string, and m is the mass of the bob?

    a. mg
    b. $T \cos \theta$
    c. $T \sin \theta$
    d. $mg \sin \theta$
    e. zero - it is in equilibrium

APPENDIX D

PROBLEMS USED IN COMPARISON OF CONCEPTUAL QUESTIONS AND ANALYTICAL PROBLEMS

Problems Used for Comparison of Conceptual Questions and Analytical ProblemS

Test Topic	Conceptual	Analytical
Electricity and Magnetism	1, 2, 3, 4, 5, 6	12, 13, 14, 15, 16, 17
Thermodynamics	1, 2, 3, 4, 5, 6, 7, 8	14, 15, 16, 17
Optics	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12	13, 14
Modern	1, 2, 3, 4, 7, 9	10, 11, 12
Mechanics	1, 2, 3, 4, 5, 6	8, 9, 10, 11, 12

APPENDIX E

SAMPLE MINILESSON OUTLINE

Lesson Outline
Refraction and Reflection
Teaching Physics using Technology
July 26, 1988
Dr. John Park, Instructor

I. Short introduction to the concepts

A. Angle references - ray angle from the normal line.
B. Define incident, reflected, and refracted ray.

II. Explain the geometry and use of the refractometer

A. Light source, detector, and potentiometers.
B. Spread of the IR light from the LED: how it differs from screen.
C. Accuracy of the refractometer - could be up to 10 degrees off.
D. Computer graphics analogy: intensity and length of plotted line.
E. Do the calibration as a group. CTRL-open apple-reset to redo.

III. Exploration Phase

A. Allow the teachers to explore on their own using the devices (approximately 15 minutes).
B. Discuss any possible discoveries.

IV. Concept Introduction

A. Continue experimentation under instructor direction.

1. Measure angles I, r, and R on both top and bottom layers.
2. Record data
3. Make calculations.
4. Plot results.
5. Repeat with another set of fluids (air/water; air/cooking oil; air/glycerine; cooking oil/water; air/glass)

B. Review the Lab. What was discovered?

V. Applications

A. Review supplemental reading material.
B. Look at the review questions, discuss applications.

Investigating Reflected and Refracted Light

After exploring using the fluid refractometer, record any notable observations and/or hypotheses here:

Structured Investigation:

Fluids being used:
Air and water
Air and glycerine
Air and cooking oil
Cooking oil and water

Data for incident light from **top fluid to bottom fluid.**

Angle of incidence	Angle of refraction	Angle of reflection	Sine of incident angle	Sine of refracted angle
1.				
2.				
3.				
4.				
5.				
6.				

Fluids being used: Air and water Air and cooking oil
Air and glycerine Cooking oil and water

Data for incident light from **top fluid to bottom fluid.**

Angle of incidence	Angle of refraction	Angle of reflection	Sine of incident angle	Sine of refracted angle
1.				
2.				
3.				
4.				
5.				
6.				

Data for incident light from **bottom fluid to top fluid.**

Angle of incidence	Angle of refraction	Angle of reflection	Sine of incident angle	Sine of refracted angle
1.				
2.				
3.				
4				
5.				
6.				

Plot a fourth graph: sin incident angle vs. sin refracted angle.

How does this graph compare with the previous graphed data?
Try to account for any differences.

Data for incident light from **bottom fluid to top fluid.**

Angle of incidence	Angle of refraction	Angle of reflection	Sine of incident angle	Sine of refracted angle
1.				
2.				
3.				
4.				
5.				
6.				

Complete the data table by calculating the sine of each incident and refracted angle.

Plot three graphs:
incident angle vs. reflected angle.
incident angle vs. refracted angle.
sin incident angle vs. sin refracted angle.

Use the two data sets in the face of the each graph. Display using two different symbols.

Select another jar with a different set of fluids and repeat the experiment. Record the data on the data sheet provided on the next page.

Summary of Reflection and Refraction Laboratory and Discussion

1. The ratio of the sine of the incident angle to the sine of the refracted angle is constant for a given frequency and media.

$$\frac{\sin \theta_1}{\sin \theta_2} = \text{constant}$$

2. The angle of incidence equals the angle of reflection.

3. The intensity of the refracted light is greatest when the incident angle is small. The intensity of the reflected light is greatest when the incident angle is large.

4. Through an analysis of wave fronts, the ratio of the sines of the incident and refracted angles is equal to the ratio of the respective velocities.

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2}$$

Therefore, as the light decreases speed when entering a new media, the light ray bends toward the normal. As the light increases speed when entering a new media, the light ray bends away from the normal.

5. If a specific frequency of light travels from a vacuum into a substance, the ratio of the sines of the incident and refracted angles is called the Index of Refraction.

$$(1) \quad \frac{\sin i_{vac.}}{\sin \theta_1} = n_1 \qquad (2) \quad \frac{\sin i_{vac}}{\sin \theta_2} = n_2$$

by dividing (2) by (1)

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1}$$

or

$$n_1 * \sin \theta_1 = n_2 * \sin \theta_2$$

6. When the light increases speed upon entering a new media, it is possible that the light will follow a path 90 degrees from the normal. The incident angle when this occurs is the critical angle. The critical angle can then be calculated using Snell' Law

$$n_1 * \sin \theta_1 = n_2 * \sin \theta_2$$

where $\theta_2 = 90°$

7. Total internal reflection will occur when the incident angle is greater than this critical angle.

8. The frequency of the light in a particular beams depends solely upon its source, while the wavelength depends on the speed of light.

For a given f:

$$\lambda_1 = \frac{v_1}{f} \quad (medium\ 1)$$

$$\lambda_2 = \frac{v_2}{f} \quad (medium\ 2)$$

$$\therefore \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

9. The index of refraction depends on, to some extent, the frequency of the light: the highest frequencies have the highest n. In glass, violet light refracts about 1% more than red light.

Interrelationships:

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

APPENDIX F

WORKSHOP SCHEDULES

The following is the spring workshop schedule:

May 12, 1988	Thursday
8:00 pm - 9:00 pm	Welcome Reception
May 13, 1988	Friday
8:00 am	Coffee and Doughnuts
8:30 am	Welcome and Introductions
9:00 am - 9:30 am	Technology Overview
9:30 am - 12:00 pm	Sampling Physics Courseware
12:00 pm - 1:15 pm	Lunch
1:15 pm - 1:45 pm	High School Physics Courses
1:45 pm - 3:45 pm	Experimentation in Physics
May 14, 1988	Saturday
8:00 am	Coffee and Doughnuts
8:30 am - 9:00 am	Review
9:00 am - 10:30 am	Session A: Homemade Devices for Interfacing (Group I) Session B: Integration of Courseware for Active Learning (Group II) Session C: Using Tool Software (Group III)
10:30 am - 10:45 am	Break
10:45 am - 12:15 pm	Repeat Sessions Session A (Group III) Session B (Group I) Session C (Group II)
12:15 pm - 1:30 pm	Lunch
1:30 pm - 3:00 pm	Repeat Sessions Session A (Group II) Session B (Group III) Session C (Group I)
3:00 pm - 3:30 pm	Closure

The following is the summer workshop schedule:

July 25, 1988	Monday
7:45 am - 8:00 am	Coffee and Doughnuts
8:00 am - 9:15 am	Business Meeting and Evaluation
9:30 am - 11:30 am	Minilesson: Measuring Capacitance
11:30 am - 12:45 pm	Lunch
12:45 pm - 2:45 pm	Minilesson: Thermal Physics
2:45 pm - 3:00 pm	Break
3:00 pm - 4:00 pm	Evaluation Project

July 26, 1988	Tuesday
8:00 am - 10:00 am	Minilesson: Reflection and Refraction
10:00 am - 10:15 am	Break
10:15 am - 12:15 pm	Minilesson: Radioactivity
12:15 pm - 1:15 pm	Lunch
1:15 pm - 3:15 pm	Minilesson: Circular Motion
3:15 pm - 3:30 pm	Break
3:30 pm - 4:15 pm	Organizational Meeting in Small Groups

July 27, 1988	Wednesday
8:30 am - 10:15 am	Working Session
10:15 am - 10:30 am	Break
10:30 am - 12:00 pm	Working Session
12:00 pm - 1:15 pm	Lunch
1:15 pm - 4:00 pm	Working Session

July 28, 1988	Thursday
8:30 am - 9:30 am	Group Meeting - Progress reports
9:30 am - 9:45 am	Break
9:45 am - 11:15 am	How to Write a Grant
11:15 am - 12:00 pm	Working Session
12:00 pm - 1:00 pm	Lunch
1:00 pm - 4:00 pm	Working Session

July 29, 1988	Friday
8:30 am - 10:30 am	Preparation of Groups for Presentations
10:30 am - 11:45 am	Group Meeting - Presentation of Modules Ideas
12:00 pm - 1:00 pm	Farewell Luncheon - Catered

1:00 pm - 2:00 pm	Evaluation Project
2:00 pm - 2:30 pm	Final Revision and Editing Session - Field Testing Plans
2:30 pm	Business Meeting

The following is the fall workshop schedule:

October 21, 1988	Friday
8:15 am	Coffee
8:30 am	Welcome and Opening Activities
9:15 am	Small Group Meetings for Work on Modules
1:00 pm - 2:00 pm	Evaluation 1
2:00 pm - 3:00 pm	Small Group Work
3:00 pm - 3:50 pm	Group 1 Presentation

October 22, 1988	Saturday
7:30 am	Coffee
7:45 am - 8:45 am	Evaluation 2
8:55 am - 9:45 am	Group 2 Presentation
9:55 am - 10:45 am	Group 3 Presentation
10:55 am - 11:45 am	Group 4 Presentation
11:45 am - 1:00 pm	Lunch
1:00 pm - 1:50 pm	Group 5 Presentation
2:00 pm	Closure Activities

APPENDIX G

RAW DATA

Raw Data Table

Sub-	Years		E & M			Mech			Modern			Optics			Therm	
			Tests			Tests			Tests			Tests			Tests	
Ject	Exp.	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
								Participants with a Physics Major								
1	5	24			23	31		46	31			36		53		
2	13	47		47	92	92	85	23	77	38	71	86	93	88		94
3	17	94		82	85	85	69	77		85	57	93	86	65		94
4	21	82	94	65	46		46	85		92	71		71	82	88	94
5	25	18	29		15	31		23	23		36		43	59	100	

Raw Data Table

Sub- Ject	Years Exp.	E & M Tests I	II	III	Mech Tests I	II	III	Modern Tests I	II	III	Optics Tests I	II	III	Therm Tests I	II	III
Participants with a Physics Minor																
6	1	53	71	71	38		54	62		85	43		57	53	71	82
7	5	47	94	94	69		46	69		77	79		71	88	94	88
8	6	24		24	23	46	46	77	77	77	64	64	50	71		65
9	10	24	53		46		46	62		69	43		36	47	76	
10	12	35		29	54	46	31	62	77	62	22	22	15	65		53
11	25	24		35	46	54	62	85	85	77	43	50	36	76		94

Raw Data Table

Sub-Ject	Years Exp.	E & M Tests I	II	III	Mech Tests I	II	III	Modern Tests I	II	III	Optics Tests I	II	III	Therm Tests I	II	III
Participants with Minimum Academic Preparation																
12	0	6		18	23		23	31		38	36		36	59	53	53
13	0		24	12	15		23	31		54	22		22	53	65	71
14	0	12	29		31			15			36			24	24	
15	0	29		24	23	31	23	46	69	31	57	86	50	59		53
16	1	29	24		38			31			43			41	71	
17	3	24	82	88	38			85		85	86		59	100	100	88
18	6	18		18	38	62	31	69	77	54	57	64	71	94		88
19	7	65	76	41	54		46	77		62	71		79	88	100	88
20	8	47		29	31	38	31	31	62	38	64	79	50	65		82
21	23	35		47	77	92	85	85	92	77	100	86	71	94		94
22	25	35	59	35	31		46	54		69	29		29	41	53	41