Determining Effects On Fifth Grade Students' Achievement And Curiosity When A Technology Education Activity Is Integrated With A Unit In Science

by

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DETERMINING EFFECTS ON FIFTH GRADE STUDENTS' ACHIEVEMENT AND CURIOSITY WHEN A TECHNOLOGY EDUCATION ACTIVITY IS INTEGRATED WITH A UNIT IN SCIENCE

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(ABSTRACT)

The purpose of the study was to explore the effect of integrating technological activities with science instruction. The researcher examined whether fifth-grade students' achievement and curiosity relative to the science unit were related to their participation in classes where the experimental treatment was employed. A secondary focus of the study was to determine whether students' curiosity about the unit prior to studying it was related to their achievement.

The researcher used a quasi-experimental, pretest/posttest design for the study. The researcher developed and field tested two instruments for use in the study: a measure of curiosity and a measure of students' science knowledge and comprehension relative to the unit studied on changing forms of energy.

The sample ($\underline{n}$=123) was drawn from a population of

fifth-grade students in Staunton and Augusta County, Virginia. Classrooms were randomly assigned as treatment and control. Treatment group teachers taught the unit by having students participate in two technological activities that corresponded with the science unit. Control group teachers used traditional science methods (i.e., primarily teacher demonstrations of science experiments) to teach the unit.

Pretest and posttest data were analyzed using correlation analysis and analysis of covariance procedures. The researcher reported a significant difference between treatment group students' and control group students' curiosity, favoring the treatment group. No significant differences were found between groups in science achievement and no significant relationship between students' curiosity and achievement was reported.

The researcher concluded that the integration of technological activities with science instruction may positively affect fifth-grade students' curiosity but may not enhance or deter from their science achievement. Hence, the science-technology linkage shows promise as a useful method of promoting greater student curiosity without negatively affecting their achievement.

Dedication

For Bob --

I didn't know him when I started this degree,

but he ended up being my best friend --

and my husband.

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Chapter One

Introduction And Rationale

Nature of the Problem

A plethora of reports released during the 1980s put the American school system in the Nation's spotlight. Unfortunately, most reports were not complimentary. They expressed dire concern about the status of education in America, often citing the need to better prepare American schoolchildren for the technological society in which they live (Mullis & Jenkins, 1988; Hurd, 1986; National Science Board Commission on Precollege Education in Mathematics, Science and Technology [NSBC], 1983).

A host of individuals and organizations responded to these reports, including educators, policy makers, and community groups. School systems around the country reacted to more than 700 new statutes within two years of the NSBC report (Futrell, 1989). Mary Hatwood Futrell, former president of the National Education Association, described this time period:

> Dictates from on high proliferated. Governors and state legislatures swept into action. Their battle cry was, "More!": more tests for students and teachers, more credits for graduation, more hours in the school day, more days in the school year, more regimentation, more

routinization, more regulation. (Futrell, 1989, p. 11)

Many educationists looked unfavorably on this response to the reform directives (AAAS, 1989; Case et al., 1984; Martin, 1985; Meeks, 1986). They cited the need to improve the *quality* of students' educational experiences rather than the *quantity* of their schooling. To them, the existing system was obsolete. It had not adjusted to the changing needs and interests of the learners. Critics of the reform initiatives argued that many American classrooms were breeding grounds for passivity. They promoted inactivity and boredom because they were highly textbook-based, rigid, and dull. Moreover, students failed to see the relevance of what they learned.

These critics contended that students were graduating with little understanding of the technological society in which they lived because typical classrooms were far removed from reality. Students did not engage in technological problem-solving. They were not challenged to critique their technological society. Most students had no direct opportunity to apply what they had learned to real experiences. Is it any wonder that they were unprepared?

The Effect of Educational Reform

The 1980s reform movement that hit American schools touched nearly every program area. But it is safe to say that science education was one of the hardest hit by criticism (AAAS, 1989; NSBC, 1983). Many reform reports accused the science education community for failing to develop students' scientific and technological literacy. Among other reasons, they blamed poor quality preparation of teachers, severe shortages of qualified teachers, and unsound educational materials and practices (AAAS, 1989; NSBC, 1983). Many criticisms were accurate; but too often the blame was misplaced. It was no secret that educators have complained about poor financial support, overcrowded classrooms, and inadequate funding for decades. These problems are most assuredly not science educators' fault given the lack of commitment to education by the voters and law makers.

Criticism of science education was not new in this country. It was also the center of attention about three decades ago when the Soviets' launching of Sputnik created a frenzy of scientific concern in the United States. Americans felt threatened by the Soviets' preeminence in space science; it was the impetus to a wide-scale (yet, temporary) reform of science education (Besvinick, 1988).

During the 1980s, Americans sensed they were losing their edge in science and technology. And, again, they turned to the scientific community, among others (i.e., business leaders, politicians), to pull them out of their slump. It was no surprise, then, that the 1980s reform directives placed a premium on developing students' scientific and technological literacy.

Concurrent Reform of Science and Technology Education

The reform reports served as a catalyst for new curriculum changes, as well as an endorsement of some changes already underway. There is evidence of this in both science education and technology education (formerly called industrial arts education).

Science education. The American Association for the Advancement of Science (AAAS) had one of the most significant responses to the reform priority. In 1989, the AAAS released a report titled, Science for All Americans. This report was a joint effort by a group of scientists and educators appointed by the AAAS and called, the National Council on Science and Technology Education (NCSTE). In this report, the NCSTE defined a scientifically literate person as:

> ...one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of

thinking for individual and social purposes. (AAAS, 1989, p. 4)

The NCSTE outlined a number of recommendations for helping students attain scientific literacy (which includes technological literacy), including a comprehensive summary of the major topics that should be covered in school science programs. Additionally, they identified the necessary considerations for achieving their recommendations. Some of these considerations are paraphrased below (AAAS, 1989, p. 5).

1. Subject matter boundaries should be eliminated or weakened to emphasize connections.
2. More attention should be given to the connections between science, mathematics, and technology.
3. Systematic research and tested craft experience about the way students learn should drive how science is taught.
4. Science teaching must be consistent with the nature of scientific inquiry and with scientific values.
5. A premium must be placed on students' curiosity and creativity.

The AAAS (1989) report made a strong statement about science education reform. It emphasized thinking skills, general concepts and ideas, and cross-subject connections. Moreover, it clearly responded to the types of criticisms that pervaded the educational reports released in the 1980s.

The AAAS report may be the most significant document outlining steps for science education reform, but it is not the only one. The science education literature is replete with recommendations on how to improve science teaching and learning. Not surprisingly, many of these ideas are reflected in the publications of the largest organization of science teachers in the world, the National Science Teachers Association [NSTA] (e.g., Bybee, Carlson, & McCormack, 1984; NSTA, 1990).

In general, other science reform proponents cited the need to put greater emphasis on creative, problem solving activities in science (Cohen & Ault in Bybee et al., 1984). Many science educators called for a renewed focus on "hands-on" science which stresses the implementation of manipulative learning activities that correspond with science content and development of science process skills (Bredderman, 1985; Donnellan & Roberts, 1985; Fort, 1990; Glasson, 1989; Kyle, Bonnstetter, Gadsden, & Shymansky, 1988; Saunders & Shepardson, 1987; Shymansky, Kyle, and Alport, 1983; Staver & Small, 1990; Tobin, Capie, and Bettencourt, 1988). They claimed that more activity-based science in schools improved students' science achievement and attitudes toward science. Other reform advocates stressed the value of making science more application-oriented (Butlin, 1988; White, 1983) or adding a technology strand in the curriculum that would show applications of science theories and concepts (Bredderman, 1987). These individuals emphasized the value of showing students the relevance and usefulness of science in their world. This was accomplished, they said, through classroom activities that show applications of scientific concepts in familiar things, like tools and machines.

A large group of science educators condoned the teaching of science from a societal issue perspective (Bybee, 1984, 1987; Bybee & Landes, 1988; Selby, 1988; Thier in Bybee et. al, 1986; Yager, 1983/1984; Ziman, 1980). These types of programs are often categorized as Science-Technology-Society (STS) and typically introduce science through social issues and themes, like population growth, pollution, and resource management.

<u>Industrial arts and technology education</u>. At the same time that science education reform was in the Nation's spotlight, industrial arts educators were already in the midst of a curriculum transition that could not have been better timed. They broadened their content base by changing their focus from industrial to general technology (International Technology Education Association [ITEA], 1985; Savage & Sterry, 1990). Furthermore, they put more

emphasis on technological problem-solving and less emphasis on technical skill development (Technology Education Advisory Council [TEAC], 1988; Waetjen, 1989). Industrial arts educators changed the name of their discipline to technology education with leadership spearheaded by the International Technology Education Association (ITEA), formerly called the American Industrial Arts Association (AIAA). Then, they embarked on a campaign to modify school curricula and improve their professional image in the schools (Starkweather, 1986). While the technology education reform movement apparently gained momentum in the early 1980's age of reform, the groundwork for the change was laid during several previous decades (DeVore, 1968, 1980; Dugger, 1988; Gradwell, 1988; Halfin, 1973; Lauda & McCrory, 1986; Olson, 1963; Scobey, 1968; Snyder & Hales, 1981; Warner et al., 1947).

Despite this heritage, most reform reports of the 1980s failed to cite this group of educators as having a contribution to make towards students' preparation for life and work in a technological society (Maley, 1984). It was partly this oversight that prompted a resurgence of efforts by technology educators to make their contributions to general education known and appreciated (ITEA, 1985; Jones & Wright, 1986; Savage & Sterry, 1990; TEAC, 1988; Technical Foundation of America [TFA], 1984; Waetjen, 1989).

These efforts may have finally been rewarded. In an unprecedented move by the science community, the significant role of technology educators towards advancing students' scientific and technological literacy was acknowledged and endorsed with the publication of the AAAS report on Project 2061 (AAAS, 1989; Johnson, 1989). This endorsement is best exemplified by this excerpt from the report:

> Traditionally, technology has been taught in diverse ways at various levels--primarily in the curricula of industrial arts, vocational education, and manual training, and in some science courses....A common theme of these activities [the classroom activities in the curricula named] is "hands-on/minds-on" education--the purposeful, intelligent honing of knowledge, talents, and skills. The Technology Panel [of the AAAS Project 2061] continually emphasized the importance of this experiential learning process, and **nearly every consultant advocated the need for more** [emphasis added]. (Johnson, 1989, p. 5)

Even before this report, industrial arts and technology educators eagerly admitted that science educators were not alone responsible for developing students' scientific and technological literacy. For example, Schmitt and Pelley (1966) reported results from their 1962-63 nationwide study of industrial arts in public schools. They surveyed school principals and industrial arts teachers to gather information about the status of industrial arts education in American schools. Both principals and teachers ranked the contribution of industrial arts towards helping students understand the application of math and science as one of its top ten objectives. This contribution is a basic component of scientific and technological literacy. Croft (1989), Smalley and Bensen (1981), and Wright (1980) expounded on the significant contributions of industrial arts and technology education towards developing students' technological literacy. They explained how industrial arts and technology education helped students to apply math and science skills to the solution of technical problems, assess technological change, and/or evaluate products of technology. Moreover, technology educators were amenable to cooperative, interdisciplinary efforts towards advancing students' scientific and technological literacy (Brusic, Dunlap, Dugger, & LaPorte, 1988; Erekson & Johnson, 1989; Gauger, 1989; McHaney & Bernhardt, 1988; Johnson, May, & DeLong, 1988; Maley, 1984, 1985a, 1985b, 1987).

From their rich heritage in industrial arts, effective technology education programs have emerged. Given the opportunity, technology educators believe these programs have the potential to make a significant contribution to students' scientific and technological literacy. This is clearly shown by the profusion of updated curricula implemented in the past decade which cite objectives that relate to the development of technological literacy (e.g., Illinois Department of Adult, Vocational, and Technical Education, 1983; New Jersey Commission on Technology Education, 1987; New Jersey Department of Education, 1990; New York State Education Department, 1987; TFA, 1984; Virginia Vocational Curriculum and Resource Center, 1988). For example, the following goals of technology education are typical of those found the curricula named; they were drawn from a brochure published by the Florida Department of Education (1990, back cover) which listed numerous goals of technology education for kindergarten through the twelfth grade. Students will:

- Safely use technological tools, materials, and processes.
- Research, plan, design, construct and evaluate problems and projects common to technological career fields.
- Experience the practical application of basic scientific and mathematical principles.
- Gain an in-depth understanding and appreciation for technology in our society and culture.
- Solve business and life problems with use of technological tools, materials, processes and

products.

Reform at the Elementary Level

Curriculum change in science and technology is imminent at both elementary and secondary levels. However, it is becoming increasingly evident that more attention must be focused on practices at the elementary school level (Mullis & Jenkins, 1986; Tilgner, 1990). This is because students in kindergarten through the sixth grade are often the most deprived when it comes to quality science and technology education. Unfortunately, many elementary teachers are intimidated by science or unprepared to teach it (AAAS, 1989; Mittlefehldt, 1985; Tilgner, 1990). Consequently, they are often poor science teachers (Fort, 1990).

Moreover, the elementary curriculum is practically void of technology education experiences (Johnson, 1989; Kieft, 1988). School curricula cater to science, not technology (Morris, 1983). While students may read about technology in social studies or touch upon it in science, they seldom have the opportunity to experience or practice it. With few exceptions, most American elementary schools do not have a technology curriculum in place. This is true despite the fact that a number of curriculum projects concerned with industrial arts and technology education were successfully implemented in American elementary schools (Dreves, 1971;

Perusek, 1980; Thrower & Weber, 1974; Wardell, 1980). In addition, technology is a recognized subject (as something different than science) and is included in the National Curriculum for schools in England and Wales (Department of Education and Science and the Welsh Office, 1990).

Moreover, research indicates that students lose their interest for science at an early age and that these attitudes are difficult to change (Mullis & Jenkins, 1988). Marked differences between boys' and girls' attitudes to science (Harvey & Edwards, 1980; Smail & Kelly, 1984) and attitudes and concepts of technology (Bame and Dugger, 1990; Raat, de Klerk Wolters, & de Vries, 1987) are also documented. These studies may help explain the gender disparity in science and technology interests and enrollments in post-elementary institutions. They also lend support to the argument that elementary level science and technology education in America demand immediate attention and reform.

The Potential Contribution of a Science-Technology Linkage

The educational reports and science education literature established a need for science education reform. The ensuing problem is to determine how that reform will take shape in American schools.

Traditionally, science educators and technology educators isolated themselves from one another. There have been scant opportunities for these educators to pool their talents and expertise. Hopefully, the curriculum reform thrust of the 1980s, coupled with concurrent reforms of both science and technology education, will unite these groups toward the common goal of preparing students to become scientifically and technologically literate. It is abundantly clear that this type of cooperative arrangement is urgently needed.

Technology educators (Brusic & Barnes, 1992; Doyle & Calder, 1989; Dunlap, Croft, & Brusic, 1992) and the AAAS (e.g., AAAS, 1989; Johnson, 1989) advocate science education reform that includes linkages with technology education. This is different than traditional science educators' efforts to include technology in their curriculum (e.g., Bybee et al., 1984; White, 1983). The former suggests a cooperative relationship between two groups of educators -- science educators and technology educators. The latter is an attempt by science educators alone to incorporate technology with the science curriculum.

The proposed linkage (subsequently referred to as a science-technology linkage) is a cooperative, educational effort. It combines the expertise of science educators (i.e., observing/describing/explaining the natural world) with that of technology educators (i.e., designing/creating/shaping the humanmade world). Furthermore, it draws attention to the fact that, while science and technology are interdependent, they are also different (Black & Harrison, 1985; Morris, 1983).

If the science-technology linkage is conceded as described, the end product would be a cohesive curriculum for students. It is supported by the reform recommendations made by the AAAS (see Johnson, 1989) and is founded on sound educational principles. The curriculum would be interesting and relevant to the educational needs of young children. Students would be involved in an interdisciplinary, application-oriented, and cooperative learning environment. Learning activities would cater to their cognitive, affective, and psychomotor needs and abilities.

This science-technology linkage may be the unprecedented resolution to the science education reform dilemma. Unfortunately, there is little empirical evidence of the success of these linkages. Curriculum endeavors of this type (e.g., Brusic et al., 1988; Gauger, 1989; Johnson et al., 1988; McHaney & Bernhardt, 1988) have not been readily condoned by the science community. They are often small scale operations. Typically, they are not experimentally tested using accepted research procedures. Educators sense that they are effective, but there is a paucity of research studies to support this claim. The few relevant studies are decades old and they predate the transition from industrial arts to technology education (e.g., Downs, 1968/1969; Logan, 1974; Pershern, 1967).

The picture is clear. America's youth deserve and require a better education in science and technology. Both science educators <u>and</u> technology educators have the responsibility to assure that it happens. The ensuing challenge is to obtain reliable and valid evidence to support the value of specific efforts to accomplish this goal. Therein lies the basis for this study.

<u>Purpose of the Study</u>

The purpose of this study was to determine if technological activities integrated with science instruction have an effect on fifth grade students' science achievement and/or curiosity, as compared to students who study the unit without technological activities. A secondary purpose was to determine if students' prior curiosity about the science topic was related to their achievement.

<u>Significance of the Study</u>

Based on the expressed need to reform science education at the elementary level, this study was conceived to respond to two aspects of the reform directive. Namely, this study examined the effect of a science-technology linkage on students' science achievement and curiosity.

There was evidence in the literature that type of knowledge measured might be affected by the teaching methodology (e.g., Glasson, 1989; Peterson, Ridenour, and Somers, 1990). Hence, science achievement was evaluated in terms of students' scores on two levels: knowledge and comprehension of the concepts relative to the unit studied. This breakdown gave the researcher a clearer picture of where technological activities might have the most influence.

The curiosity component of this study was significant for two reasons. First, research shows that there is a relationship between curiosity, motivation to learn, and achievement (Ball, 1977; Day, Berlyne, & Hunt, 1971; Fowler, 1965; Maw & Maw, 1961b; Russell, 1971). And second, if the integration of technological activities can positively affect students' curiosity, they may serve a valuable function in the elementary science curriculum. They stimulate curiosity and they potentially promote achievement. These outcomes are consistent with the reform directives.

Research Questions

This study addressed three general research questions:

1. What effect does students' participation in a science unit enhanced with technological activities

have on their science achievement (at the knowledge-level and comprehension-level), as compared to students who participate in a science unit without technological activities?

2. What effect does students' participation in a science unit enhanced with technological activities have on their curiosity as compared to students who participate in a science unit without technological activities?
3. What is the relationship between students' curiosity and achievement (at the knowledge-level and comprehension-level) in a science lesson?

Assumptions

The following assumptions were made with regard to this study:

1. Participating teachers in this study followed the unit plan and time specifications provided to them when implementing the unit.
2. Variables that were uncontrollable in the intact classes (i.e., learning style, socioeconomic status, intelligence) were equally distributed across groups and would have an equal effect on treatment and control group scores.
3. Students were not informed of their participation in

the study before or during the experiment.

4. The instruments used to measure students' science knowledge and comprehension and curiosity were reliable and valid measures.
5. Students' prior knowledge of the unit content and prior curiosity about the topics were reliably measured using the same instruments validated for the post-test.
6. The researcher was effective in informing treatment group teachers about the methods used to integrate technological activities with a science unit.
7. Treatment group teachers were qualified teachers who were capable of integrating the technological activities with a science unit.

Limitations

There were two limitations considered in this study.

1. The lack of standardized instruments pertinent to this study necessitated the development and validation of original instruments.
2. The science unit chosen for this study (Changing Forms of Energy) was determined by the participating classroom teachers based on their needs and the study's time frame.

Delimitations

Delimitations were necessarily imposed on this study due to financial and time constraints.

1. The study was confined to the fifth grade level.
2. The sample was drawn from two school districts in the same general area that expressed the interest and willingness to participate in this study.
3. The length of time devoted to the delivery of the unit was limited to 10 school days.
4. Science content was limited to that which participating teachers determined was important for inclusion in the unit plan and which was included in their science textbook, Discover Science, Teacher's Annotated Edition (Guy, Miller, Roscoe, Snell, and Thomas, 1989).

Operational Definitions

For the purposes of this study, the following definitions were employed.

Control group. Students in classrooms where the traditional instructional method (control method) was used by classroom teachers to teach science.

Control method. The traditional instructional method used by classroom teachers to teach science which did not include the integration of technological activities.

Curiosity. A measure of the student's desire to know about things associated with the unit as shown on the instrument, My Point of View (MyPOV).

Daily plan. An outline intended for teachers' use to guide their implementation of a unit of study. It identifies appropriate instructional strategies that a teacher should use for daily lessons.

Mission 21 program. A technology education program developed at Virginia Polytechnic Institute and State University and designed to be implemented in grades one through six. Students' attention is focused on solving technological problems and students are required to keep journals documenting their problem-solving and thought processes (Brusic et al., 1988).

Overall science achievement. A score on the posttest used to measure students' science knowledge and comprehension, What I Know About Changing Forms of Energy (WIKACFE), which is adjusted to control for students' prior knowledge and comprehension as measured by the WIKACFE pretest.

Participating teachers. Selected classroom teachers who volunteered to take part in this study as either control group teachers or as treatment group teachers.

Science comprehension. Ability to recall and demonstrate fuller understanding of specific facts or concepts from the unit by applying the knowledge to a different situation or recognizing it in a new format or paraphrased version. Comprehension is the second lowest level of understanding according to Bloom's (1956) taxonomoy of educational objectives.

Science comprehension achievement. A subscore on the posttest, What I Know About Changing Forms of Energy (WIKACFE), which included only those items identified as measuring students' science comprehension which is adjusted to control for students' prior science comprehension as measured by the WIKACFE pretest.

Science knowledge. Ability to recall specific facts or concepts with little or no change from the way they were presented during the unit. Knowledge is the lowest level of understanding according to Bloom's (1956) taxonomy of educational objectives.

Science knowledge achievement. A subscore on the posttest, What I Know About Changing Forms of Energy (WIKACFE), which included only those items identified as measuring students' science knowledge which is adjusted to control for students' prior science knowledge as measured by the WIKACFE pretest.

Science-technology linkage. The term given to an educational effort cooperatively developed between a science educator and a technology (industrial arts) educator.

Technological activity. A classroom project drawn from the Mission 21 program concept and designed to enhance specific science concepts by encouraging the student to apply knowledge, creativity, and resources to solve a practical problem.

Technology education. The discipline that has a heritage in industrial arts and is concerned with "the study of the application of knowledge, creativity, and resources to solve problems and extend human potential" (TEAC, 1988).

Treatment group. Students in classrooms where teachers integrated technological activities with science instruction (treatment method).

Treatment method. The instructional method which involved the integration of technological activities with science instruction. This method employs the science-technology linkage concept.

Unit of study. A body of content chosen for instructional purposes.

Unit plan. An organized outline of the concepts included in a unit of study.

Summary

A number of educational reports cited a need for improved science and technology education. They called for reform at all levels in the educational system.

One response to the reform directives came from the American Association for the Advancement of Science [AAAS] (AAAS, 1989; Johnson, 1989). It echoed the pleas of many technology educators who believe a linkage between technology education and science education makes science curriculum more interesting and relevant for learners. While this move appears educationally sound, it is not experimentally proven to be successful.

This study was a preliminary attempt to provide support for such linkages. Specifically, the purpose of the study was to determine if technological activities integrated with science instruction had an effect on fifth grade students' achievement (at the knowledge-level and comprehension-level) and/or curiosity in a science lesson, as compared to students in science classes who did not engage in technological activities.

Chapter Two

Review of Related Literature

The intent of this chapter is to review and synthesize literature relative to the scope of this study. It is divided into four sections each focusing on a particular aspect of research relevant to this study.

The first section provides support for the experimental treatment used in this study, called the science-technology linkage. It provides an explanation of what this treatment entails and shows support for it from the literature. It elaborates on the information provided in the first chapter of this report which stated that educators believed that these types of curricular connections were valuable.

The second section describes a theory base for the study. It provides an overview of pertinent educational theories that support a science curriculum supplemented with relevant technological activities. Furthermore, it introduces the theory of curiosity which lends support to the inclusion of this variable in the study.

The third section reviews research on science achievement. It examines factors related to students' science achievement that are pertinent to this study. Moreover, it provides justification for the variables used in this study.

The fourth section stems from both the second and third section of this literature review. It focuses on curiosity and provides further evidence to support the inclusion of this variable in the study. It clarifies the relationship between curiosity and interest, highlights research related to curiosity and achievement, and examines factors concerned with measuring it.

Section One: The Science-Technology Linkage

The science-technology linkage served as the experimental treatment in this study. It is further described as a method of teaching science content that involved the integration of relevant, meaningful technological activities with science instruction and a period of reflection on what was done.

This technique was adopted from Mission 21, a technology education program for the elementary school, which was developed at Virginia Polytechnic Institute and State University (Virginia Tech) under a grant from the National Aeronautics and Space Administration (Brusic et al., 1988; Brusic & Barnes, 1992; Dunlap, 1990; Dunlap, Croft, & Brusic, 1992). In this section, the Mission 21 program is explained, similar programs are compared, and research related to science-technology linkage programs at the elementary level is presented.

The Mission 21 Program. Classroom teachers using the Mission 21 program incorporated technological activities with their regular instruction in order to enhance concepts and skills in specific subjects such as science. In addition, Mission 21 students kept folios (journals or logs) about their experiences and presented their work to peers and/or adults. The folios and presentations enabled students to reflect on their work and share their accomplishments.

Mission 21 activities, called "design briefs," were developed and field tested in about thirty Virginia classrooms in grades three through six. At the time of this study, first and second grade field testing was in the early stages of development and field testing.

Literature pertaining to this program is mostly descriptive in nature, with one exception. Dunlap's (1990) dissertation research focused on whether third and fourth grade students exposed to the Mission 21 program developed different attitudes toward technology than students who did not receive such exposure. He found that boys and girls who participated in the Mission 21 program did have significantly more positive attitudes toward technology than students who did not participate in the program.

While further empirical evidence of the program's effectiveness is lacking, Mission 21 project staff indicated that implementation efforts were successful (Brusic et al., 1988). Furthermore, articles published in local newspapers (e.g., Skinner, 1988; Wilmoth, 1988) and personal correspondence to the research associates (P. Farmer, personal communication, September 9, 1988; C. Hurst, personal communication, March 9, 1988) supported this claim. There is also a section in the Mission 21 program guides that features field test site teachers' experiences with the program (Brusic & Barnes, 1992; Dunlap, Croft, & Brusic, 1992). This section lends additional support to the staff's claim that the program was effective.

As of this writing, the Mission 21 program was the most comprehensively packaged program in existence for the implementation of elementary level technology education. In addition to activities that were specifically correlated with concepts and skills in each subject, it provided classroom teachers with an effective rationale for including technological activities in the elementary school curricula and it outlined numerous approaches for implementation.

Other Elementary Level Technology Programs. Other technology education programs for elementary schools existed, but they were not completely congruent with the philosophical approach used in Mission 21. Nor were they as complete. In most cases, they were compilations of manipulative, constructional, or technological activities rather than articulated and field-tested educational programs (Lucy, 1988; Thode, 1988; Virginia Vocational Curriculum and Resource Center, 1988). Information in some of these other programs indicated that there were connections to typical elementary subjects (i.e., science, social studies), but these connections were often unclear or insufficient.

The Mission 21 program was based on the premise that technology education in the elementary school should be interdisciplinary; it should be integrated with other subject areas. In contrast, curriculum materials from the New York State Department of Education (NYSDE, no date) and Thode (1988) seemed to focus on technology as a separate subject matter to be taught by regular classroom teachers. Both of these packages included an assortment of interesting activity suggestions, however, connections to other subject areas were absent or assumed. The materials developed through the New York Energy Education Project (1984) did specify how activities supported specific science understandings, skills, and attitudes. However, the program appeared to be primarily science-oriented (i.e., theory-based) and assumed technological connections rather than specifying them.

Two separate programs were reviewed which were developed in New Jersey. One program was known as

"Technology For Children" [T4C]. The T4C program was first developed in the early 1970s through the New Jersey State Department of Education. It was considered a unique prevocational program for elementary schools. Several studies related to T4C were conducted and reported which show that the program emphasis was clearly career-oriented, not general technology (Perusek, 1979; Wardell, 1980). While these studies clearly showed the value of the program, they were not related to the present study's purposes. Not one of the T4C studies specifically examined the effect of the program on students' achievement in a particular subject (i.e., science) or their curiosity about specific topics. Wardell (1980) did examine the effect of the T4C program on students' school or career motivation, but she did not specify individual subject matter.

A second New Jersey program was developed and pilot tested in the Bernardsville School System (Department of Design and Technology, 1990). This K-12 program shows a nice articulation of concepts and skills from kindergarten through the 12th grade. However, general implementation guidelines necessary for elementary school teachers who are unfamiliar with teaching technology are lacking. Furthermore, the program was primarily intended for local use and is not available to teachers nationally.

Moreover, the relationship between science and technology is either absent or vaguely mentioned in every other elementary level technology education program reviewed. The Mission 21 program clearly made this a priority and it was vital to the present study.

Additionally, each of the other programs or packages was developed for local or statewide implementation rather than national diffusion. The only exception to this was the packet of materials available from the Technology Education for Children Council (Lucy, 1990). This packet was intended for use in any number of settings. However, it was not a complete program with a consistent rationale and philosophy; it was mostly a compilation of useful activities. This factor significantly contributed to the preference for Mission 21 materials which would be readily available for use both nationally and internationally.

<u>Related research at the elementary level</u>. As stated previously, empirical research to support the value of science-technology linkage programs at the elementary level was weak. By far, the most substantial research was conducted two to three decades ago. Studies conducted by Champion (1965), Downs (1969), Logan (1973), and Pershern (1967) provided evidence that industrial arts (technology) activities integrated with science instruction at the elementary level had positive effects on students' science

achievement and/or attitudes. Each of these researchers integrated industrial arts type activities with traditional science instruction using an experimental (or quasi-experimental) design with treatment and control groups. While each researcher used a slightly different approach to integrating industrial arts with science (experimental treatment) than the method used in the present study, the studies clearly lend support to the inclusion of these types of activities with science instruction.

Champion (1965) conducted his study around a science unit on weather. He reported that students in the experimental group scored significantly higher on a post-unit examination relative to the unit studied. In addition, students in the experimental group reported doing considerably more outside (non-assigned) reading than the control group. Teachers felt that this was one indication of students' greater interest and motivation. Downs (1969) and Logan (1973) found that hands-on (industrial arts-type) learning techniques significantly enhanced students' science learning. Pershern (1967) found that students' achievement scores were not significantly different between treatment and control groups but that their scores on attitude questionnaires were, favoring the treatment group approach.

Another study conducted by Gerne (1967) compared students' achievement in a science unit on electricity and magnetism. His experimental groups used a special electrical board to learn about these concepts; control groups learned the concepts through the traditional textbook approach. While Gerne found no significant differences in achievement, students' scores on an attitude questionnaire favored the experimental approach.

Most other elementary level industrial arts studies reviewed were descriptive in nature and typically dealt with general aspects of including industrial arts with the elementary curriculum (i.e., philosophy, need, types of programs, goals). This was verified by Downs' (1974) comprehensive survey which determined the status of research related to elementary school industrial arts. Downs reported 58 doctoral level studies and 66 master's degree level studies conducted and completed between 1930 and 1974 that dealt with elementary industrial arts. Of these 124 studies, only 28 were experimental studies. Of these, only four studies were related to assessing the value of industrial arts (technology) education towards science achievement. These were the ones reported previously (Champion, 1965; Downs, 1969; Gerne, 1967; Pershern, 1967).

Section Two: A Theory Base for the Study

In any profession, theories provide a basis upon which people practice (Richmond, 1968). This is true in engineering, science, law, and education. Therefore, it is important to defend the techniques used in this study by showing theoretical support for their employment in this study. The experimental treatment in this study was the integration of a technological activity with a science unit, called a science-technology linkage. It was more completely described in Section One of this review of literature. It is supported by a number of educational theories, described next, that emphasize the value of active participation in the learning process and the importance of relevant experiences towards helping students construct their own scientific and technological knowledge. Additionally, theoretical support for the inclusion of the curiosity component in this study is shown.

Theories behind technological activities used in technology education. Technology educators put a number of theories into practice in their classrooms. According to Donald Maley, an influential technology educator and harbinger of science-technology linkages, technology educators apply at least four theories in particular. These theories represent the combined views of a number of noted educational theorists (e.g., Jean Piaget, Jacques Rousseau, Jerome Bruner). Maley (1982, p. 4) lists and briefly describes the pertinent theories:

- **Theory of purposeful learning**: The meaningfulness of the educational experience and the degree to which it is in keeping with the purposes of the learner are determinants of the level and quality of learning that will take place.
- **Theory of individual differences**: The effectiveness of the educational processes, strategies, and programs is directly related to the degree to which these elements are in harmony with and supportive of the physical, emotional, philosophical, and sensory functioning of the individual.
- **Theory of multisensory learning**: Optimum learning about most topics or items is dependent on the degree to which all of the senses (seeing, hearing, tasting, etc.) can be brought to bear on the subject.
- **Theory of involvement in learning**: The degree and quality of the learning are dependent on the level and kind of involvement by the learner with the subject.

The experimental treatment used in this study was based on educational theories applied in technology education, as described by Maley (1982). These theories are clearly evident throughout the Mission 21 program materials. For example, program activities stress the involvement of learners and they are highly experiential and manipulative in nature. Activities cater to the interests of learners at the prescribed age level and they are flexible enough to conform to individual needs and abilities. Teachers are encouraged to modify activities to accommodate individual needs and numerous recommendations are provided on how this can be done. Additionally, activities are purposeful. Since the activities are presented in the context of a real or hypothetical situation, students can more easily see the relevance of their work.

Theory of experience. John Dewey, a noted educational philosopher of the early twentieth century, delineated another relevant theory in a number of his writings (Dewey, 1917, 1963, 1969). In brief, Dewey's theory of experience emphasized the value of quality experiences towards helping a person learn and grow.

> Everything depends upon the *quality* of the experience which is had...the central problem of an education based upon experience is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences. (Dewey, 1963, pp. 27-28)

Dewey contended that educative experiences, in contrast to miseducative ones, derived from previous experiences and led to quality future experiences. He called this the "continuity of experience or...the experiential continuum"

(Dewey, 1963, p. 28). In his opinion, non-connected experiences were miseducative because they were not cumulative and they were inefficient. According to Dewey, a gratifying experience can be miseducative if it is isolated and does not promote growth and development. Dewey (1963) elaborated on this theory by describing a quality experience:

> ...if an experience arouses **curiosity** (emphasis added), strengthens initiative, and sets up desires and purposes that are sufficiently intense to carry a person over dead places in the future, continuity works in a very different way. Every experience is a moving force. (p. 38)

Dewey asserted that traditional education mostly provided students with miseducative experiences. These experiences caused them to dislike books and associate learning with boredom. Moreover, these experiences were distinctly different from life outside the school; students could not apply what they had learned and saw no relevance to the "real" world. It was for this reason that Dewey firmly believed that shops (industrial arts) and kitchens (home economics) served a central purpose in schools (Dewey, 1963). Consequently, Dewey's theory had a profound influence on early industrial arts programs, especially at the elementary level (Bonser, 1932; Bonser & Mossman, 1930).

Theory of experiential learning. The theory of experiential learning is also directly supportive of the science-technology linkage. While it is not specifically linked to a single theorist or philosopher, the underlying premises of experiential learning are found in the work of William James (in Donaldson & Vinson, 1979), David Kolb (1984), and John Dewey (1917; 1963).

The theory of experiential learning is based on the premise that people learn best by doing. Proponents of this theory are concerned for the total development of the individual -- social, intellectual, and psychological. They argue that development is threatened when students are thrust into a typical school situation that:

> ...increasingly isolates young people from the kinds of experiences, encounters, and challenges that form the basis for healthy development and that add purpose and meaning to formal education. (Conrad & Hedin, 1981, p. 6)

Experiential educators (those that follow the theory of experiential learning) believe that there is great value in school programs that are experience-based and relevant to students. They characterize experiential education as:

> ...a pedagogy of theory and curriculum which utilizes direct experience as a basic tenant for learning and

teaching. Experiential education encourages the connection of concrete experiences with abstract thinking to facilitate learning. (Association for Experiential Education, 1990, page not numbered)

Furthermore, many experiential educators stress the importance of reflective experiences. These are defined as opportunities for individuals to ponder their experiences through written or verbal dialogue.

The theory of experiential learning overlaps those theories identified by Maley (1982) but calls attention to the role of experience in helping students understand abstract concepts. It is germane to the science-technology linkage since it is believed that technological activities are a concrete way of helping students understand abstract scientific concepts. Moreover, it places great emphasis on the role of reflection in learning.

The constructivist theory of science learning and teaching. Theorists supporting a constructivist view of science learning and teaching believe that people construct their own knowledge about the world based on their own experiences (Duckworth, 1986; Kuhn, 1970; Pope & Gilbert, 1983; Von Glasersfeld, 1989; Vosniadou & Brewer, 1987). They believe that learning is most meaningful and lasting when it is constructed by the learner and has personal relevance.

This view is likewise supported by Jean Piaget's constructivist epistemology which emphasized the importance of children's interaction with the environment as a means of constructing their view of the world (Pope & Gilbert, 1983; Schwebel & Raph, 1973).

The constructivists' view has relevance in the science-technology linkage since it places great value on active learning accompanied with a verbal expression of ideas. According to the constructivists, it is through this verbal expression that students can express their true understanding or interpretation of information. In turn, teachers can better comprehend what learners think. Eleanor Duckworth (1986), a former student of Piaget, described the role of the teacher in a constructivist environment:

> ...put students in contact with phenomena related to the area to be studied--the real thing, not...lectures about it...help them notice what is interesting...engage them so they will continue to think and wonder about it...have the students try to explain the sense they are making...try to understand their sense. (pp. 481-482)

Theory of curiosity as a motivation to learn. Curiosity, as a construct, will be elaborated on later. However, it is useful at this point to examine how curiosity factors into theories of learning. Unfortunately, few educational theorists have subscribed themselves to this topic despite the fact that curiosity is often cited as an important factor in learning. Theoretical literature in this area is scant and it is most often subsumed under broader theories of motivation (see Ball, 1977; Russell, 1971; Voss & Keller, 1983).

Perhaps the most noted theorist on curiosity is D. E. Berlyne. Berlyne's (1954a; 1960) theory of human curiosity is based on a behavior theory approach which emphasizes a human drive to want to know. According to Berlyne, this drive increased in relationship to the intensity of the drive stimulus and the conflict it caused.

By conflict, Berlyne referred to the discord created when something seemed incongruous with past experience or was simply not known but of interest. Hence, when people saw or heard something that imposed a conflict (e.g., how does a starfish eat?), then they were driven into a state of curiosity. This curious state was only relieved when they were satisfied with what they learned about the curiosity stimulus.

Berlyne (1954a, 1954b) explained that curiosity was stimulated by probing questions or situations that were novel, strange, or surprising. People in a curious state strived to reduce their drive state by engaging in a variety of responses. These responses included focused thinking about it, careful or specific observation, or "recourse to authority" (1954a, p. 183). In this last response, the individual referred to published information or expert opinion.

Berlyne's theory of curiosity is supported by the work of a number of others involved in curiosity research (e.g., Day, 1968; Maw & Maw, 1964) who believe that heightened curiosity facilitates learning. Collectively, they lent support to the current study by emphasizing the value of learners' curiosity for enhancing learning. It was believed that the science-technology linkage would enhance students' learning by either capitalizing on their curiosity or promoting greater curiosity. This was believed true because the technological activities catered to elementary students' natural curiosity to know about things in their world. Additionally, the technological problem-solving approach created conflicts that were believed to stimulate students' curiosity motivation to learn.

Section Three: Factors Related to Science Achievement

Researchers have long been interested in identifying factors related to students' science achievement. They believed that unlocking the key to why some students achieved and others did not would help science educators plan and implement more effective curricula. Furthermore, researchers clearly pointed out that there were many ways of assessing achievement. Students may achieve in one area (i.e., analyzing scientific data) and not succeed in another (i.e., recall scientific vocabulary).

Certain findings were relatively consistent in these science achievement studies which were pertinent to the framing of the present study. In this section, these findings are reported in five sub-sections: gender, type of program, type of achievement measure, curiosity, and other factors.

Gender. A number of studies and reports expressed concern about the unequal representation of females in secondary and college science courses and science-related careers (Campbell, 1986; Klein, 1985; Lockheed, Thorpe, Brooks-Gunn, Casserly, and McAloon, 1985). Various reasons were cited for this discrepancy, including discrimination and bias.

However, some educational researchers thought that this variance might also be explained by probing the interaction of gender with science achievement in schools. The results from two large scale studies showed that there was only a significant relationship between gender and achievement favoring boys in physical science (Mullis & Jenkins, 1988;

Smail & Kelly, 1984a). In fact, this disparity may be explained by boys' hobbies and household tasks, not their science education (Smail & Kelly, 1984a). Interestingly, these study findings indicated that differences were less significant at the elementary school level and became greater as students progressed through school. However, this conclusion may suggest that even small differences in the elementary school may be significant if they predict greater disparity in later years.

Type of program. An abundance of studies focused on the discrepancies in students' achievement as they related to the type of science program studied. The findings in this area were remarkably consistent. Studies at both elementary and secondary levels showed considerable support for science programs that were labeled "hands-on" or "active" (Bredderman, 1982, 1985; Glasson, 1989; Mullis & Jenkins, 1988; Saunders & Shepardson, 1987; Shymansky et al., 1983; Tobin, 1988; Tobin et al., 1988). These hands-on programs were activity-oriented; they typically made extensive use of laboratory activities (usually experiments) and minimal use of textbooks, lectures, or teacher-only demonstrations. While many of the science-type of hands-on activities (e.g., conducting experiments) may have had a different emphasis than that used in the present study (e.g., solving a practical, technological problem), they did lend support to the notion that students' active involvement in science led to greater achievement. Moreover, this benefit was especially manifest with economically or academically disadvantaged youth (Bredderman, 1982).

Additionally, research on teaching and learning indicated that girls may benefit from certain types of science teaching more than others (Campbell, 1986; Mullis & Jenkins, 1988). For example, Mullis & Jenkins (1988) made this recommendation:

> ...to counteract the aversion toward physical science that girls seem to develop...elementary science should include an abundance of hands-on activities related to concepts in electricity, magnetism, and other areas, structured so that girls play an active rather than passive role. (p. 9)

Type of achievement measure. Many science education researchers have expressed concern about the types of measures used to assess students' achievement (Educational Testing Service and National Assessment of Educational Progress [ETS/NAEP], 1987; Glasson, 1989; Hein, 1987). A great percentage of science achievement measures used in various studies tested students' mere recall of facts and concepts. These tests seldom assessed students' higher order thinking skills, problem-solving competence, or ability to apply their knowledge. As a result, many study findings may not be showing a true picture of students' achievement. This was especially believed to be true when "hands-on" or process-oriented learning was involved.

For example, researchers from ETS/NAEP found differences among students' achievement when they probed students' science understandings at five proficiency levels (Mullis & Jenkins, 1988, p. 37):

Level 150 -- Knows everyday science facts

Level 200 -- Understands simple scientific principles

Level 250 -- Applies basic scientific information

Level 300 -- Analyzes scientific procedures and data

Level 350 -- Integrates specialized scientific information

ETS/NAEP found that students' performance decreased as questions pertained to higher levels. Higher level questions required greater application of scientific knowledge and more specialized information (Mullis & Jenkins, 1988). While the ETS/NAEP studies do not address the question of whether hands-on science makes a difference in students' achievement at various levels, they do show that differential achievement levels are an important consideration in science learning. Glasson's (1989) study attempted to address this question more directly. He assessed students' achievement in two categories under two instructional methods. Glasson used Anderson's (1985) distinction between declarative knowledge and procedural knowledge to test whether hands-on laboratory methods were superior to teacher demonstration laboratory methods in promoting students' science achievement.

> Declarative knowledge refers to knowledge about facts and things; procedural knowledge refers to knowledge about how to perform various cognitive activities. Procedural knowledge fundamentally has a problem-solving organization. (Anderson, 1985, p. 198)

Glasson (1989) found that ninth-grade students in the class employing hands-on laboratory methods performed significantly better on a test of procedural knowledge than students in a teacher demonstration class. Both groups scored equally well on a test of declarative knowledge.

Further evidence of differential achievement effects between hands-on science and other teaching methods is shown in two meta-analysis studies (Bredderman, 1982, 1985; Shymansky et al., 1983). Both of these studies examined students' achievement in the hands-on, activity-centered science programs popularized during the late 1960s and early 1970s (i.e., ESS, SCIS, SAPA). Both studies showed clear evidence that students in these programs outperformed students in comparison classrooms. This superior performance was shown on measures of science achievement in a range of areas that could be categorized as testing different levels of knowledge. Shymansky et al. (1983) made this conclusion:

> ...Students exposed to new science curricula performed better than students in traditional courses in general achievement, analytic skills, process skills, and related skills (reading, mathematics, social studies and communication), as well as developing a more positive attitude toward science. On a composite basis, the average student in new science curricula exceeded the performance of 63% of the students in traditional science courses. (p. 387)

To emphasize the significance of these findings, the magnitude of these meta-analyses should be noted. Bredderman (1985) estimated that his synthesis involved more than 1,000 classrooms and 12,000 students. Shymansky et al. (1983) estimated that their analysis of 105 experimental studies included more than 45,000 students.

These findings about differential effects of achievement measures greatly influenced the development of the science test used in the present study, What I Know About Changing Forms of Energy (WIKACFE). The WIKACFE test integrated questions which tested two levels of understanding: knowledge and comprehension. These are two of several levels described by numerous instructional design specialists (Bloom, 1956; Bloom, Madaus, and Hastings, 1981; Vargas, 1972). According to these educators, knowledge is the lowest level of understanding and "...implies the recall or recognition of specific elements in a subject area" (Bloom et al., 1981, p. 213). Vargas (1972) explains that knowledge objectives "...can be learned by rote memory with little or no 'understanding' of what is repeated" (p. 119).

According to Bloom (1956), Bloom et al. (1981), and Vargas (1972), comprehension builds upon knowledge. It requires the student to recall and recognize information well enough to be able to paraphrase it, interpret it, and/or extrapolate from it. Comprehension is a higher level of understanding which requires a more thorough assimilation of the material.

Curiosity. While curiosity is often cited as an important trait in scientists and scientifically literate individuals (AAAS, 1989; Koran & Longino, 1982), there is a dearth of research on the role of curiosity in science achievement, especially at the elementary level (Harty & Beall, 1984). Studies conducted by Campbell (1971), Harty and Beall (1984), Jenkins (1969), Peterson and Lowery (1968), and Smail and Kelly (1984b) represent the bulk of experimental research into curiosity and science. However, only two of these studies addressed the relationship between curiosity and science achievement (Campbell, 1971; Smail & Kelly, 1984b).

Campbell's (1971) study primarily focused on the relationship between teachers' instructional interaction and their students' cognitive and affective process development. One component of Campbell's affective scale included a measure of scientific curiosity. Campbell concluded that students had more positive gains (cognitively and affectively) when teachers used indirect methods of instruction. It is difficult to determine from Campbell's study whether curiosity had any direct relationship to students' achievement.

Smail and Kelly (1984b) measured 11-year old children's science curiosity as part of a series of cognitive and affective tests to examine sex differences in science and technology. The only significant difference in science achievement between boys and girls was in physical science, which slightly favored boys. This corresponded with a similar finding on their science curiosity scale which showed girls' science curiosity as particularly low. The researchers did not provide further details about their findings related to curiosity and achievement.

Most other research on curiosity is of a general nature and exists outside the science and technology education literature (e.g., Berlyne, 1954a, 1954b, 1960, 1966a, 1966b;

Day, 1968, 1971; Maw & Maw, 1961a, 1961b, 1964, 1968). However, the absence of studies in science education does not necessarily constitute a lack of relevance. In fact, in Koran's & Longino's (1982) synthesis of research related to this topic, they stated that curiosity was significant in science because curious children "...explore objects and events with a greater number of their senses and for longer periods of time, thus understanding better what they are experiencing, remembering it better, and facilitating more complete concept learning" (p. 19).

The relevance of science curiosity towards enhancing science achievement was also indirectly supported through research in gifted education. Several researchers noted that gifted science students exhibited curiosity among other traits (Consuegra, 1982; Dirkes, 1981, Follis & Krockover, 1982). This observation is pertinent in that it provides support for possible linkages between science curiosity and achievement. Most gifted science students are identified by their high science achievement scores.

Other factors. Many factors, other than those highlighted previously, may influence science achievement. For example, data from the NAEP (Mullis & Jenkins, 1988) indicated that students entered schools with unequal opportunities. According to this report and another

(Lockheed et al., 1985), Black and Hispanic students were at a considerable disadvantage. The NAEP report goes on to suggest that this may be attributed to the fact that larger percentages of these students came from "homes of lower socioeconomic status" (Mullis & Jenkins, 1988, p. 8). Campbell (1986) emphasized that these differences were not due to their natural ability (i.e., genetics), but instead, the minorities' different backgrounds and experiences. Researchers also pointed out that these differences were either non-existent or less pronounced in the elementary school years than later (Lockheed et al., 1985).

Not surprisingly, studies have also shown that teacher behavior and style may have an effect on student achievement. Matyas and Kahle (cited in Mullis & Jenkins, 1988) claimed that some teachers had higher expectations of boys and they asked them higher-level questions. Furthermore, a growing body of literature showed that the types of experiences students had outside of school (i.e., their hobbies) may have significantly affected their participation and achievement in science (Mullis & Jenkins, 1988; Smail & Kelly, 1984b).

As one would expect, studies also showed a positive, direct relationship between amount of science instruction and students' achievement (Mullis & Jenkins, 1988; Murnane & Raizen, 1988). Likewise, these same reports cited a similar correlation between amount of homework and science achievement. Researchers with the NAEP (Mullis & Jenkins, 1988) emphatically pointed out that their study's results did not suggest a cause-and-effect relationship; they simply indicated a positive relationship. Consequently, the researchers urged further studies to more closely examine the nature of this relationship.

In the present study, most of these potential variables could not be measured or controlled, with the exception of amount of science instruction. It was assumed that all the other variables would have equal effects across groups. This assumption was plausible since the treatment was randomly assigned to teachers and groups were heterogeneous. Amount of science instruction was partially controlled by specifying approximate time constraints on the unit plan and providing daily lesson plans to all teachers. It was assumed that teachers adhered to these time frames as closely as possible.

Section Four: Curiosity

Previously, curiosity was identified as a legitimate factor to consider when studying students' achievement, including science achievement. It was shown that students' curiosity had relevance in science education and that there was a need for further research in this area to determine the exact nature of the relationship. In this section, previous research on curiosity in general is summarized that was pertinent to the present study's problem and methodology. It is presented in four sub-sections: defining curiosity, curiosity and interest, curiosity and achievement, and measuring curiosity.

Defining curiosity. Most parents and educators know intuitively when a child exhibits curiosity. But, in order to measure curiosity and apply the findings to the improvement of instruction, a precise definition of the term becomes necessary. Moreover, it is essential that researchers clearly differentiate between curiosity and mere interest.

Maw and Maw (1961) provided a popular definition of curiosity after they conducted a comprehensive review of literature. Their widely cited definition (see Day, 1971; Keller et al., 1978; Koran & Longino, 1982) was actually a description of how an elementary school child demonstrates curiosity. The child:

1. reacts positively to new, strange, incongruous, or mysterious elements in his [her] environment by moving toward them, by exploring them, or by manipulating them,
2. exhibits a need or a desire to know more about

himself [herself] and/or his [her] environment,

3. scans his [her] surroundings seeking new experiences, and/or
4. persists in examining and exploring stimuli in order to know more about them. (Maw & Maw, 1964, p. 31)

Based on this definition, curiosity can be narrowly defined as "a desire to sense and a desire to know" (Keller et al., 1978, p. 38). However, to add clarification to the term, these two aspects of curiosity were further separated in the literature (Berlyne, 1954a). Perceptual curiosity described the desire to sense and epistemic curiosity denoted the desire to know. Both of these are evidenced in Maw & Maw's (1964) definition. Of these two types of curiosity, epistemic curiosity was considered more relevant in education (Keller et al., 1978; Vidler, 1977) and it was the type of curiosity examined in this study.

While this categorization is useful, researchers found it necessary to classify curiosity even further into state curiosity and trait curiosity. According to Keller et al. (1978), persons exhibiting any or all of the behaviors stipulated in the Maw and Maw (1964) definition were in a state of curiosity; they exhibited state curiosity. If people had a tendency or inclination to exhibit these behaviors often, they had a trait of curiosity; they exhibited trait curiosity.

While Day (1971) mostly agreed with the Maw and Maw (1964) definition, he felt that they described two other types of curiosity: specific and diversive. According to Day, specific curiosity subsumed statements numbered 1, 2, and 4 in the Maw and Maw (1964) definition quoted previously. The third statement in the Maw and Maw definition clearly described diversive curiosity. Day explained that specific curiosity was a response to certain stimulation which elicited a reaction or certain arousal level that led to specific exploration. This type of curiosity is similar to reactive curiosity as described by Penney & McCann (1964). Diversive curiosity, on the other hand, led to general (diversive) exploration. Day (1971, p. 101) explained that diversive curiosity was often a response to "...a situation of changelessness, repetition, or monotony."

For the purposes of clarification, the present study probed students' curiosity behaviors in one particular situation whereby curiosity was expected in specific areas. Hence it clearly examined state or specific curiosity, not trait or diversive curiosity.

Curiosity and interest. While these descriptions of curiosity appear to frame this psychological construct quite effectively, confusion is often generated when the term is used synonymously with interest. It is not uncommon to find teachers saying, "students showed interest in this," when they actually meant that students were curious about it. These students exhibited curiosity because they asked more questions and they wanted to explore it at length. Curiosity and interest are invariably misconstrued by many, even researchers. For example, Smail and Kelly (1984b, p. 90) stated, "Interests are by no means fixed, but an initial curiosity about a topic can motivate pupils to successful study." This statement is confusing because one does not know whether they are talking about students' interests or their curiosity.

This confusion would be considerably alleviated if researchers adhered to the differentiation described by Jenkins (1969) or Maw (1971). Jenkins (p. 128) stated that interest and curiosity had similar effects on people but that they were distinguished by the "presence or absence of a connected goal." He explained that curiosity was exhibited when there was no "...connected, clearly defined goal toward which the individual is pointed" (p. 128). Individuals exhibited mere interest, as opposed to curiosity, if that goal was clearly defined and connected to the interest. This explanation can be clarified by providing a specific example. In the present study, curiosity was measured, not interest. If interest were measured, the instrument would have focused on a specific goal (i.e., students' likes or dislikes about the unit studied). The goal of the instrument used in the present study was much broader and more ambiguous than that. The purpose of the instrument was to determine if the unit influenced their desire to know more about the topics studied. In other words, the instrument did not merely probe their interest in the unit; it investigated their curiosity about things that may have been fostered through this specific school experience.

Maw (1971) defined curiosity somewhat different than Jenkins (1969) when he considered it to be an advanced level of interest. He differentiated between curiosity and interest by describing a young boy who collected things in his pockets. The things he collected reflected the types of things that interested him (i.e., stones, stamps, and marbles). It was only when he adhered to something in particular (i.e., the stamps) and began to notice peculiar things about them (i.e., different perforations or colors) that his interest reached an advanced level and was labeled curiosity.

Curiosity and achievement. Few researchers have concerned themselves with exploring the effect of curiosity on achievement by examining it experimentally (Berlyne, 1954b, 1966; Day, 1968; Maw and Maw, 1961b; Paradowski, 1967). These investigations were in addition to those studies identified previously which specifically explored the relationship between students' curiosity and science achievement (e.g., Campbell, 1971; Smail & Kelly, 1984b).

Each of these general investigations into the curiosity-achievement relationship provide support for educators' widely held belief that curiosity is positively related to achievement. Paradowski (1967) found that curious undergraduate students scored significantly higher when tested for intentional and incidental learning. Likewise, Berlyne (1966a) found that high school students who expressed curiosity about a component of his lesson performed significantly better on tests measuring their retention of specific facts. Maw and Maw (1961b, 1964) were the only researchers in this group that worked with elementary school students. One of their studies (1961b) showed that fifth-grade students identified as highly curious were able to recall more information than low curiosity students who were matched for intelligence. Their other study (1964) with fifth-grade students showed a positive correlation between highly curious children and learning. According to their study results, highly curious children:

- Asked more and better questions,

- Gave more correct answers to general information questions, and
- Remembered more novel and unusual information one week after they were presented with it.

In some cases, researchers have tried to explain curious students' achievement by attributing it to intelligence instead of curiosity. While there is some support in the literature for this explanation (e.g., Maw & Maw, 1961a, 1975), many researchers have found the correlation low and insignificant (Day, 1968; Maw & Maw, 1961b; Penney & McCann, 1964).

Measuring curiosity. There was considerable agreement in the literature that valid and reliable measures of curiosity were scarce (Harty & Beall, 1984; Maw & Maw, 1968; Penney & McCann, 1964). This was especially true at the elementary school level and in the area of state or specific curiosity (Keller et al., 1978; Leherissey, 1971). This scarcity may well explain the shortage of empirical research in this area. A large proportion of the work done in curiosity measurement has focused on trait or diversive curiosity (i.e., Day, 1971; Hogan & Greenberger, 1969; Maw & Maw, 1968; Penney & McCann, 1964; Peterson & Lowery, 1968) and has been highly concentrated on upper grade levels, including college students.

Curiosity measures developed by Harty and Beall (1984), Jenkins (1969), Richardson (1971), and Smail and Kelly (1984b) were the only ones found that appeared to assess elementary school students' state or specific curiosity. Coincidentally, each of these measures was directly linked to science education. Only the one developed by Jenkins, however, focused on students' curiosity about specific concepts associated with a particular science unit (chemical energy).

The instruments developed by Harty and Beall (1984), Richardson (1971), and Smail and Kelly (1984b) primarily focused on general science curiosity, although they did indicate how their instruments measured various dimensions of curiosity. Surprisingly, each researcher used a considerably different system for classifying their curiosity dimensions.

Harty and Beall (1984) identified four curiosity factors in their curiosity scale: novelty, lack of clarity, complexity of stimuli, and surprise/bafflement. These factors were derived from general curiosity research reported by Berlyne (1954a, 1954b), Penney and McCann (1964), and Jenkins (1969).

Richardson (1971) assessed a number of dimensions of interest and curiosity using his instrument. In addition to specific dimensions (e.g., plants and rocks, animals), he also used general dimensions like overall interest in science, general curiosity about surroundings, mechanical synthesis and analysis, and observational processes.

Smail and Kelly (1984b) reported four distinct scales on their 42-item instrument: physical science, nature study, human biology, and spectacular science. The authors noted that this fourth category was the most ambiguous and that it included topics often featured in television programs and magazines. It should be noted, however, that this distinction was not so obvious when examining these particular items on their instrument. For example, spectacular science included animals in the jungle, volcanoes and earthquakes, and fossils.

It is also interesting to note how each of these four instruments differed in terms of format. Three studies employed similar methods in that they presented students with a series of statements like, "I like to talk about the planets and stars" (Harty & Beall, 1984, p. 428). Students using Harty's and Beall's (1984) instrument responded by either agreeing or disagreeing with these statements. Smail and Kelly (1984b) presented students with a list of science topics (e.g., how our muscles work, what baking powder does) and students indicated whether they wanted to know more about a particular topic or whether they were not interested.

Jenkins (1969) used a unique approach to his instrument's design which he modified from a technique introduced by Berlyne (1966b). Jenkins presented students with a series of questions in groups of three. Students were asked to choose the one question in each group whose answer they most wanted to know. Jenkins planted one question in each group pertaining to the conceptual scheme (chemical energy) he was interested in measuring. He considered students' selections of questions related to chemical energy to be representative of their curiosity towards that scheme.

A fifth curiosity measure of relevance to the present study was developed by Leherissey (1971a, 1971b). Her instrument, called the State Curiosity Scale (SCS) or State Epistemic Curiosity Scale (SECS), was validated with female undergraduate students. It was a self-report scale consisting of twenty items which probed students' specific, epistemic curiosity with regards to selected learning materials. However, the instrument was worded in general terms and could be applied to a variety of learning situations (Keller et al., 1978; Leherissey, 1971). Many of the statements were based on validated items on the Ontario Test of Intrinsic Motivation (see Day, 1971). Other statements were constructed by the researcher and were based on concepts supported in the curiosity literature. For example, statements requested students to indicate their desire to know more, to approach novel tasks, to approach complex or ambiguous tasks, and persist in information-seeking behavior. Sample statements included, "I thought it was fun to increase my understanding about the subject matter" and "I enjoyed learning the material which was unfamiliar to me" (Leherissey, 1971a, p. 12). Students responded to each item on a 4-point scale ranging from "not at all" to "very much so."

Leherissey's (1971a) SECS was particularly useful in the development of the curiosity instrument used in the present study. It provided a solid foundation from which appropriate statements were developed to assess elementary school students' curiosity towards a specific unit of study.

Summary

Research was reviewed and synthesized relative to the scope of the present study. It was presented in four sections which focused on the experimental technique used in the study (the science-technology linkage), the theory base for the study, factors related to science achievement, and curiosity.

It was shown that a science-technology linkage at the elementary school level is a valid instructional approach based on theories of learning and curiosity. In addition, it has the potential to positively affect students' science achievement.

It was also shown that curiosity may be significantly related to students' science achievement and that gender may play a role in achievement, especially if the topic is related to physical science. Further, it was shown that students' achievement can be measured in different ways. These findings lent support to the framing of variables for the present study.

Chapter Three

Methodology

Introduction

In this chapter, the methodology employed in this study is explained. Details of the experiment are discussed in three sections. The first section focuses on the design of the study and it includes five subdivisions: hypotheses, sample, research design, instrumentation, and data analysis.

The second section of this chapter outlines the procedures followed in organizing and conducting the study. It clarifies how the study was implemented in the schools and data were collected. It provides a detailed explanation of how the unit plan, treatment group materials, and control group materials were developed.

The third section of this chapter focuses on the development and validation of the curiosity measure and science test used in this study. The process for creating the instruments, field testing them, and assessing them is described. Reliability estimates are reported.

An itemized summary of the procedures followed in conducting this study is found in Appendix A. This chart illustrates the researcher's step-by-step process in conducting this study from identification of the sample through data analysis.

Section One: Design of the Study

The purpose of this study was to explore the effect of integrating technological activities with science instruction (called a science-technology linkage). The researcher examined whether students' achievement and change in curiosity were related to their participation in classes where the experimental treatment was employed. A secondary focus of the study was to determine whether students' curiosity about the unit prior to studying it was related to their achievement. The researcher used a quasi-experimental, pre-test/post-test design for the study.

Hypotheses. Based on the review of literature and research questions posed in Chapter One, the following hypotheses were stated.

1. Students studying a science unit accompanied by technological activities (treatment group) will have higher overall science achievement levels than students studying the unit without technological activities (control group), controlling for prior overall science knowledge and comprehension.
2. Students studying a science unit accompanied by technological activities (treatment group) will have higher science comprehension achievement levels than students studying the unit without technological

activities (control group), controlling for prior science comprehension.

3. There will be no difference between treatment group students' and control group students' science knowledge achievement, controlling for prior science knowledge.
4. Higher curiosity students (before the unit) will have higher overall science achievement levels than lower curiosity students (before the unit), controlling for prior overall science knowledge and comprehension.
5. Students studying a science unit accompanied by technological activities (treatment group) will become more curious about the unit topic than students studying the unit without technological activities (control group), controlling for prior curiosity.
6. There will be no difference between boys and girls overall science achievement levels, controlling for prior overall science knowledge and comprehension.
7. Girls studying a science unit accompanied by technological activities (girls in treatment group) will have higher science knowledge and science comprehension achievement levels than girls studying the unit without technological activities (girls in

control group), controlling for girls' prior science knowledge and comprehension.

8. Girls studying a science unit accompanied by technological activities (treatment group girls) will become more curious about the unit topic than girls studying the unit without technological activities (control group girls), controlling for girls' prior curiosity.

<u>**Sample**</u>. The sample used in the present study was drawn from a population of fifth grade students in Staunton and Augusta County, Virginia. This area is located in north central Virginia and is divided into two separate school districts. One district administration controlled city schools; the other district administration controlled all other schools in the county.

The sample consisted of 123 students enrolled in three schools within these two districts and within two miles of each other. Students were enrolled in heterogeneous classrooms which remained intact throughout the study. Table 3.1 shows the breakdown of the sample in terms the number of classrooms involved and the total participation of boys and girls.

The sample was chosen based on input provided by school district administrators. The researcher first proposed the study to the school district administrators. The administrators decided which schools in their district would be available for this type of study. The city administrators sought participation of individual classroom teachers and presented the researcher with their names. The county administrator introduced the researcher to three school principals; the researcher then sought participation of individual teachers. The researcher randomly assigned the treatment to three of these classroom teachers. The other three classroom teachers served as control group teachers. Table 3.2 illustrates the participation of boys and girls in treatment and control groups.

Table 3.1

Number of Boys and Girls in Sample by School and Classroom

School	Boys	Girls	Total
School I			
Classroom A	12	10	22
Classroom B	9	11	20
School II			
Classroom C	9	12	21
Classroom D	7	12	19
Classroom E	8	11	19
School III			
Classroom F	15	7	22
Total			123

Table 3.2

Number of Boys and Girls in Treatment and Control Groups

Group	Boys	Girls	Total
Treatment			
Group T-1	9	11	20
Group T-2	7	12	19
Group T-3	8	11	19
Total Treatment	24	34	58
Control			
Group C-1	9	12	21
Group C-2	12	10	22
Group C-3	15	7	22
Total Control	36	29	65
Total Sample			123

Research design. This study employed a quasi-experimental, nonequivalent control group design as described by Campbell and Stanley (1963). This design was appropriate given the fact that treatment and control groups were drawn from intact, heterogeneous fifth grade classrooms which did not have pre-experimental sampling equivalence. However, the groups were as similar as availability permitted and the treatment was randomly assigned to classroom teachers. Every group took the same pretest and posttest at approximately the same time. Figure 3.1 on the following page graphically illustrates this research design.

As is the case with any quasi-experimental design, there were many threats to internal and external validity. Internal validity was described by Campbell and Stanley (1963) as the "...basic minimum without which any experiment is uninterpretable..." (p. 5). Internal validity is affected when extraneous variables produce effects that may confound the effect of the treatment. External validity relates to an experiment's generalizability. It enables the researcher to ask questions like, "To what populations, settings, treatment variables, and measurement variables can this effect be generalized?" (Campbell & Stanley, 1963, p. 5).

According to Campbell and Stanley (1963), a number of variables can affect the internal validity of quasi-experimental designs. These are history, maturation,

Pretest	Treatment	Posttest
O	X	O
Pretest		Posttest
O		O

Figure 3.1. Graphic Representation of the Research Design

testing, instrumentation, regression, selection, mortality, and the interaction of these sources.

History is defined as the events that happen between the pretest and posttest which are in addition to the treatment. History causes problems in some research designs when there is a time lapse between testing of the treatment and control groups. This was not a problem in the present study since all students from treatment and control groups were tested at approximately the same time.

Maturation refers to things that happen as a result of the passage of time, like getting older or growing tired. In the present study, it was assumed that maturation had an equal effect on all students in both the treatment and control groups. This was plausible since students took pretests and posttests at approximately the same time.

In some studies, it is believed that testing (pretesting) threatens internal validity by affecting how subjects respond on the posttest (Campbell & Stanley, 1963). While this is especially true when a research design engages some subjects in pretests and not others, it is also possible in other designs. If a pretest sensitizes subjects to a topic or problem, it is possible that the subjects' attention will become more focused. This may change the effect of the treatment. In the present study, it was believed that effects of pretesting would be equal across groups because all groups were pretested and posttested.

Instrumentation becomes a threat to internal validity when there are "...changes in the calibration of a measuring instrument or changes in the observers or scorers..." (Campbell & Stanley, 1963, p. 5). Neither the science test or the curiosity measure were calibrated differently or scored differently on the posttest. Hence, this was not a concern in the present study.

Research designs whose validity were threatened by selection typically involved differential selection of groups or subjects. This was not the case in the present study for three reasons which were all related to the sampling procedure described earlier. First, all teachers volunteered their classes' participation in this study. Nine teachers were asked to participate in the study and only one teacher declined. Of the 8 participating teachers, two served as field test teachers and 6 participated in the study. Furthermore, all schools were located within the same geographic area so it was less likely that effects were due to particular factors associated with certain schools. Second, teachers of heterogeneous classes were randomly assigned to treatment and control groups. Third, the treatment and control groups were consistent from the pretest to the posttest. There was no differential selection of participants in the present study, hence, selection was not a threat to the internal validity of the present study.

Mortality becomes a threat to internal validity when there is a loss of subjects in the comparison groups from either absenteeism or incomplete data. This is a common problem in classroom research when students miss classes during the pretest, treatment, or posttest. This problem was alleviated by omitting all data from students who did not complete the same pretest and posttest (i.e., curiosity measure or science test). In addition, classroom teachers kept attendance records throughout the unit. The researcher used these records to determine whether certain students' scores should be omitted from analysis due to their absenteeism during the unit implementation even though they may have been present on test-taking days. Statistical analysis showed that there was negligible change in the results when selected students' scores were omitted due to absenteeism. This analysis was consistent for students with high and low absenteeism. Due to the negligible change and the small number of students involved, the researcher determined that all students' scores would be included in the analysis if they met the first criterion of being present for both the same pretest and posttest.

Campbell and Stanley (1963) explained that two factors account for most of the internal validity problems for this research design. They are regression and interaction of any previously cited sources (i.e., selection-history, selection-testing, selection-maturation).

Regression refers to the tendency of extreme scores to move toward the mean. It is typically a problem when groups are selected for their extremities (e.g., students who failed a test or psychotic patients). Regression was not a problem in this study since students were considered to represent a typical range of fifth grade boys and girls. Students were not selected or grouped into treatment or control classes based on their pretest results.

Although unlikely, the interaction of selection with history, maturation, and testing represents a second threat to the internal validity of this research design (Campbell & Stanley, 1963). These interactions were not of concern in the present study since it was believed that selection was not of particular concern in this study's sampling procedure. Again, the sample was drawn from intact, heterogeneous classrooms; teachers were randomly assigned to treatment and control conditions.

External validity is affected by two factors. First, it can be affected by the interaction of testing (or selection) with the treatment. Second, external validity is affected by reactive arrangements. Campbell and Stanley (1963) explained that: "The sources of external validity are thus guesses...as to what factors lawfully interact with our treatment variables, and, by implication, guesses as to what can be disregarded" (p. 17). These factors must be considered in order to determine the generalizability of the study.

In the present study, external validity was possibly threatened by the interaction of testing with the treatment. But, this threat was extremely small since all students in control and treatment groups were pretested and posttested. Moreover, the tests were not so dissimilar to tests taken by elementary school students. Thus, it was highly unlikely that any undesirable interactions took place.

Reactivity is a prominent source of external invalidity in a number of research designs. When students are aware of their participation in an experiment they no longer represent a typical group of students. Hence, generalizability is greatly reduced. Campbell and Stanley indicated that taking random samples of students from intact classrooms "...is almost certain to be the more reactive, creating more awareness of experiment, I'm-a-guinea-pig attitude, and the like" (p. 50).

In the present study, reactivity was controlled in two ways. First, students were never informed of their participation in the experiment. Teachers in control and treatment group settings were instructed to keep this information confidential and to provide students with plausible explanations of anything that might indicate experimental involvement. Second, all groups were intact classes. By keeping groups of students together with their usual peers and maintaining the regular teachers during the treatment period, the possibility of students realizing that they were involved in an experiment was greatly reduced.

Instrumentation. Two instruments were used in this study. One instrument measured students' curiosity (My Point of View [MyPOV], Form A and B) and the other measured their understanding of the science concepts relative to the unit of study (What I Know About Changing Forms of Energy [WIKACFE]). The curiosity measure was separated into two forms to accommodate the special wording needs of the pretest (form A) and the posttest (form B). The science test was identical for both the pretest and posttest. Students recorded all of their answers on special machine-readable, computer forms that could be optically scanned into the computer for analysis purposes.

Both instruments were developed by the researcher since there were no other validated instruments available. A thorough description of the development and validation process for both instruments is found in Section Three of this chapter.

Data analysis. The researcher used the SAS software package on the Virginia Tech mainframe computer to analyze data and compute descriptive and inferential statistics. A correlation matrix was developed for all the variables in the study. Analysis of covariance (ANCOVA) procedures were used to test pertinent research hypotheses since it was desired to increase the precision of the analysis by controlling for students' pretest scores on the MyPOV and WIKACFE instruments. All hypotheses were tested at the .05 level of significance.

Section Two: Organization of the Study

The researcher organized the study to make it feasible to integrate it with existing school curriculum and cause as little disruption as possible. In order to accomplish this goal, the following considerations were made and procedures were followed.

Choosing a unit. Once the environmental setting and key personnel were selected, the researcher sought the input of classroom teachers to identify an appropriate unit of study for this research project. It was imperative that all participating teachers consented to teaching the same unit during the same time frame. Likewise, the two teachers who agreed to field test the materials prior to the study were consulted.

The researcher met or spoke with all classroom teachers at their respective schools. During these discussions, teachers provided the researcher with information about the types of science units that they would be willing to teach during the approximate time period that the study needed to be conducted. The researcher synthesized the information collected from all sites and identified one unit that was mutually acceptable to all teachers. A letter verifying the teachers' agreement with this unit was sent to all participating teachers. It specified the general nature of the unit and the approximate implementation time frame. (See Appendix B for a copy of this letter.)

Developing a unit plan. Once the unit was identified, the researcher sought teachers' input regarding the concepts to be taught in this unit. All teachers were invited to submit information to the researcher in the form of lesson plans, unit plans, or curriculum guidelines that were relevant to the unit. The researcher used the science textbook as the primary guide, synthesized the information collected, and produced a draft unit plan.

All participating teachers and field test teachers reviewed and edited the draft unit plan. Based on their feedback, the researcher revised the unit plan. This draft of the unit plan was deemed acceptable by all teachers and was used in this study by the field test teachers, control group teachers, and treatment group teachers. The unit plan is displayed in Appendix C.

Developing treatment materials. Once the unit plan was finalized, the researcher developed two appropriate technological activities that corresponded with the chosen unit plan. These activities would be the unique feature of the experimental treatment approach. They met certain predetermined criteria which the researcher identified through the review of literature on educational theories and elementary level technology education programs. The chosen activities fit within these general guidelines. They:

- Were *meaningful* or *relevant* to the student,
- Were flexible enough to accommodate *individual differences*,
- Were *multisensory*,
- Promoted *active involvement* on the part of the student,
- Clearly *showed connections* between science and technology, and
- Provided opportunities for students to *construct their own ideas* about the topic and *express them orally or in writing.*

Likewise, the activities had to fit the activity format and implementation style of the Mission 21 program (see

Brusic & Barnes, 1992; Dunlap, Croft, & Brusic, 1992). This decision was made based on a review of existing technology education programs at the elementary level. The Mission 21 program appeared to be the most comprehensive technology program for this level and it was the only one which was field tested and readily accessible to classroom teachers. In order to fit within the guidelines of the Mission 21 program, the technological activities chosen for this research study met these criteria:

- The activities were appropriate for implementation in a typical elementary classroom using *common materials*.
- The activities were presented to the student in the form of a *practical problem* to be solved,
- Students solved the problem by exploring possible solutions and *creating at least one solution*,
- Students described their problem-solving and thought processes in a *journal*.

Based on these criteria, the researcher developed acceptable technological activities and necessary support materials. The technological activities were first reviewed, and subsequently approved, by three individuals associated with the Mission 21 project, one science teacher educator, and one science education graduate student. These individuals are listed in Appendix D. See Appendix E for copies of the technological activities with their accompanying instructions.

The researcher provided each treatment group teacher with specific instructions on how to implement the unit and record student absences. These general guideline sheets and a sample recording form are presented in Appendix F. The treatment group daily plan is shown in Appendix G. All materials necessary to implement the unit and conduct the technological activities with every student in the class was provided to treatment group teachers. Appendix H shows a list of materials provided to each treatment group teacher.

Developing control group materials. In order to maintain some consistency between implementation in each of the control group classrooms, the researcher developed a suggested daily plan for these teachers to follow. Teachers were given specific instructions on how to implement the unit. Instead of hands-on technological activities, the teachers were instructed to demonstrate a few experiments which were a part of the regular textbook study. The daily plan given to each teacher included exact instructions as to which experiments they should demonstrate from the science book. The control group daily plan is shown in Appendix I. The general guideline sheets and forms for recording student absences were the same as those used for treatment group teachers (Appendix F). All materials necessary to implement the unit and demonstrate the experiments were provided to control group teachers. Appendix J shows a list of materials provided to each control group teacher.

Training treatment group teachers. The researcher presented the technological activities and implementation guidelines to all treatment group teachers during a 2-hour workshop. The workshop was similar in format to those workshops conducted by Mission 21 project staff when they were training their field test site teachers. See Appendix K for a copy of the workshop agenda.

During this workshop, teachers engaged in the technological activities in order to prepare themselves to conduct the activities in their classrooms. Likewise, they were given hints and guidelines on how to effectively integrate them with the science unit. Every teacher was trained to implement the technological activities in a similar way and engage their students in some form of journal keeping. To encourage journal keeping, the researcher provided each treatment group teacher with blank-paged booklets for each student to use. In addition, teachers were instructed on how to administer the pretests and posttests for measuring curiosity and science knowledge and comprehension. Teachers left this meeting with a complete set of materials to use during their implementation process, except for the pretests and posttests. All testing materials were delivered to the school 1-3 days prior to the date that teachers needed them.

Providing guidelines to control group teachers. The researcher met with all control group teachers shortly after the unit plan was finalized. These 30-60 minute meetings took place in each school where control group teachers were based.

During these meetings, control group teachers were given instructions on how to administer the pretests and posttests. In addition, teachers were provided with copies of the unit plan (Appendix C) and the daily plan (Appendix I). Teachers left these meetings with a complete set of materials to use during their implementation process (see list in Appendix J), except for the pretests and posttests. All testing materials were delivered to the school 1-3 days prior to the date that teachers needed to use them.

Conducting the study and collecting data. Teachers administered the curiosity pretests one or two days before they started teaching the unit; they administered the science pretests one school day before the unit began. Science pretests and posttests were consistently administered after the curiosity measures. As stated in the test administration directions, teachers assured students that these tests would not affect their grades. Students wrote their names on the answer forms for the sole purpose of giving the researcher the information needed to code each form with a machine-readable number. When the forms were scanned into the computer, individual students' names could not be identified; only their identification number appeared on printouts. Students were informed that the information gathered from these tests was needed to help teachers deliver this unit more effectively.

As specified on the unit plan, all control group teachers and treatment group teachers implemented the unit during a similar time frame. The teachers commenced and concluded the unit at approximately the same time. Every teacher taught science at approximately the same time during the day for nearly the same number of minutes. Table 3.3 shows these data for each of the control group teachers and treatment group teachers.

Table 3.3

Summary of Implementation Time Frame Followed by Treatment and Control Group Teachers

Group	Start Date (1991)	No. Days Spent	Total Time Spent/Unit (minutes)
Treatment			
Group T-1	4/12	10	305
Group T-2	4/4	10	335
Group T-3	4/8	10	340
Control			
Group C-1	4/8	10	305
Group C-2	4/12	10	310
Group C-3	4/8	10	330

The researcher never visited classrooms at any time during the course of the study. Teachers delivered all completed pretests and posttests to their main office and the researcher collected the packets there. All teachers were contacted by phone within a few days of unit commencement to verify that everything was progressing smoothly.

All teachers administered the curiosity posttests one school day after the unit was completed. Teachers administered the science test within 48 hours after the administration of the curiosity test. Once again, students were assured that their test answers would not affect their science grades. After these data were analyzed, all teachers were sent a brief summary of the results for their particular class and letters thanking them for their involvement in the study.

Section Three: Development and Validation of the Instrumentation

Since validated instruments were unavailable for measuring students' curiosity or science knowledge and/or comprehension relative to the topic studied, they were both developed and validated for this study. This process is described in this final section of the chapter.

The basis for the development of the curiosity measure. The researcher identified only one validated instrument during the review of literature that was pertinent to the present study. This instrument was called the State Epistemic Curiosity Scale (SECS; Leherissey, 1971a, 1971b). Leherissey also referred to it as the State Curiosity Scale (SCS) in some of her writings. The SECS became the basis for the curiosity measure developed for the present study.

Leherissey (1971a, 1971b) used the SECS in studies she conducted with women enrolled in a college class. The SECS was a self-report scale which assessed "... a student's level of state epistemic curiosity aroused by the learning materials" (Leherissey, 1971a, p. 9). Leherissey used the SECS in her study to investigate the effect of stimulating students' state epistemic curiosity within a computer-assisted instruction (CAI) task. However, Keller et al. (1978) noted that the SECS was generically written and could be easily applied in a number of learning situations.

The SECS consisted of 20 statements which required subjects to report how they felt about learning materials at a particular point in time (i.e., prior to learning them or after learning them). Leherissey (1971b) generated two forms of the scale to make it useful at different points during the learning cycle. For example, subjects were presented with statements like, "It will be exciting to me to learn about this subject" (p. 120) when taking form A of the SECS administered before the lessons began. On form B which was administered at the conclusion of the CAI task, students responded to the statement: "It was exciting to me to learn about this subject" (p. 122). Students replied by marking a response on a four-point scale: not at all (1), somewhat (2), moderately so (3), or very much so (4). Students' scores were computed by totalling these responses once corrections were made for negatively worded statements. High scores were assumed to be indicative of higher curiosity; low scores were assumed to be indicative of lower curiosity. Scores ranged from 20 to 80.

Leherissey's (1971a) development and validation of the SECS was thorough. Scale items were partially drawn from a previously validated instrument for measuring intrinsic motivation and new items were developed based on theories published by noted researchers in this field (i.e., Berlyne and Day). Leherissey (1971a, 1971b) conducted several studies to validate the SECS. She reported remarkably high reliability coefficients ranging from .81 to .94.

Additionally, Leherissey (1971a) cited evidence of the construct validity of the SECS by correlating students' scores on the SECS with scores on other instruments. She compared students' scores on the SECS with scores on an instrument that measured their intrinsic motivation. It was expected that there would be a positive correlation between the two and this hypothesis was shown to be true. As further evidence, she computed correlations with students' scores on an instrument measuring their state anxiety. Research shows that curiosity and anxiety are inversely related and Leherissey's computations supported this. Moreover, Leherissey found significant positive correlations between students' SECS scores and their achievement on the CAI task. Since state epistemic curiosity is assumed to be positively related to improved performance, this finding also supported the construct validity of the SECS.

Development of the curiosity measure. The researcher developed the curiosity measure for the present study based on Leherissey's (1971a, 1971b) SECS. The revised instrument was titled, My Point of View (MyPOV), to make it more suitable for fifth grade students' use. Two forms of the instrument were developed to meet the special needs of the pretest (form A) and posttest (form B). These forms corresponded with Leherissey's forms of the same name.

Each of the 20 items on the MyPOV instrument directly correlated with a statement on the SECS. The meaning inherent in each of Leherissey's statements was maintained as much of possible. Changes were made to statements for three reasons only: 1) to reduce the reading level, 2) to make statements clear and concise for younger students, and 3) to make the instrument appropriate for use with a particular unit instead of general learning materials. See Appendix L and M for a parallel comparison of statements from the SECS and the revised version of the MyPOV instrument (forms A and B).

In addition to the changes made to individual statements on the SECS to create the MyPOV instrument, the researcher also changed the response choices and instructions. This was necessary in order to meet the needs of the present study and to cater to the ability level of fifth grade students. Leherissey used a four-point response scale ranging from "Not at all" (1) to "Very much so" (4). On the MyPOV instrument, students responded by marking "Agree" (1) or "Do Not Agree" (0). Students' scores were computed by totalling these responses once corrections were made for negatively worded statements. Higher scores were assumed to be indicative of higher curiosity; lower scores were assumed to be indicative of lower curiosity.

Once the MyPOV instrument was written, it was shown to a panel of experts who assessed whether the changes made to the instrument were acceptable. The panel of experts consisted of five individuals with expertise in either educational measurement, science education, technology education, or fifth grade teaching; their names and areas of expertise are shown in Appendix N. These individuals evaluated the MyPOV instrument by completing an assessment form (Appendix O).

A summary of experts' comments is shown in Appendix P. Changes were made to the instrument based on the experts' recommendations and the instrument was prepared for field testing. Leherissey's instruments (forms A and B) are shown in Appendix Q. Samples of the MyPOV instrument, which reflect changes made after the experts' evaluation, are found in Appendix R (pretest) and Appendix S (posttest) along with the teachers' instructions for administering them.

Field testing of these instruments took place along with field testing of the science test and technological activities. This process is described in the last part of this section beginning on page 91.

Development of the science test. The researcher developed the science test for this study based on the unit plan (appendix C). The instrument was titled, What I Know About Changing Forms of Energy (WIKACFE) and was used in its same form for both the pretest and posttest. All of the multiple-choice items on the WIKACFE instrument were directly related to concepts presented on the unit plan.

Once the researcher developed a draft of the WIKACFE instrument, it was presented to a panel of five experts. This panel of experts (shown in Appendix N) included individuals with expertise in educational measurement, science education, technology education, or fifth grade teaching. The experts evaluated test items in four areas by completing an assessment form. The draft test and the evaluation form are shown in Appendices T and U, respectively. Reviewers rated the WIKACFE instrument in terms of content, fifth-grade readability and format, and type of knowledge tested. A summary of experts' comments is shown in Appendix V.

Based on reviewers' comments, numerous changes were made to the instrument. Most significantly, the researcher determined that the categorization of test items as measuring declarative knowledge and procedural knowledge was questionable. The test reviewer with the greatest expertise in this area was not convinced that many test items were based on procedural knowledge. Instead, the reviewer suggested that test items measured other lower levels of understanding such as those described by various instructional designers (e.g., Bloom, 1956; Bloom, Madaus, and Hastings, 1981; Vargas, 1972). Upon further examination of the test and further review of literature, it was determined that this criticism was valid.

As a result, the researcher developed a new classification system for test items in cooperation with the expert reviewer who recommended a more appropriate categorization. Each test item was categorized as measuring students' knowledge or comprehension of unit concepts. An item was categorized as measuring science knowledge if it measured students' ability to recall specific facts or concepts with little or no change from the way they were presented in the unit. An item was categorized as measuring science comprehension when it measured students' ability to recall and demonstrate fuller understanding of specific facts or concepts from the unit by applying the knowledge to a different situation or recognizing it in a new format or paraphrased version. Table 3.4 shows the breakdown of test items in each of these categories; numbers shown are taken from the revised version of the test used in the study (appendix X).

Table 3.4

Identification of WIKACFE Items as Testing Students' Science Knowledge or Science Comprehension

Category	Questions from WIKACFE Test'	TOTAL per Test
Science Knowledge	2; 3; 4; 10; 11; 12 14; 15; 16; 17; 18; 20; 21; 22; 23; 25; 30; 32; 33; 34; 35; 36	22 items
Science Comprehension	1; 6; 7; 8; 9; 13; 19; 24; 26; 27; 28; 29; 31; 37; 38	15 items
TOTAL TEST ITEMS		37 items

' All test item numbers taken from the revised version of the WIKACFE test as shown in appendix X.

Note: Item #5 was omitted from analysis because it was later determined that there may be more than one answer.

Based on the input from all test reviewers, specific items on the draft version of the WIKACFE test were revised, deleted, or replaced. A new version of the test was then prepared for field testing. See appendix W for a copy of the WIKACFE instrument as it was used during the field test stage of this study and which reflects changes made after the experts' evaluation. Field testing of this instrument took place along with field testing of the curiosity measure and technological activity. This process is described in the next section.

Validation of instruments. The results found and the conclusions made in the present study were highly dependent on the validity and reliability of the MyPOV instruments and the WIKACFE instrument. Both reliability and validity were assessed and shown to be acceptable for both instruments used in the present study through an expert review and field testing process.

Validity refers to the extent which scores on the measurement instrument can be interpreted as representing the construct or concepts of interest. Showing evidence of test validity enables the researcher to draw inferences (Crocker & Algina, 1986).

Evidence of the validity of the MyPOV instruments was demonstrated in a different way than it was on the WIKACFE instrument. The MyPOV instruments were derived from a previously validated instrument called the SECS (Leherissey 1971a, 1971b) which was shown to have high content and construct validity. The panel of experts who reviewed the MyPOV instruments agreed that the wording changes made to the SECS (forms A and B) to create the MyPOV instruments (forms A and B) were acceptable once minor changes were made after the review process. Hence, it was assumed that validity of the instruments remained intact. See Appendix P for a summary of the experts' reviews.

The WIKACFE instrument was subjected to review by another panel of experts. These individuals assessed whether the questions on the WIKACFE instrument did, indeed, reflect the content of the unit plan. Further, they categorized questions as to the type of knowledge being tested: declarative or procedural. Although the labeling of the categories was later changed (i.e., most items labeled declarative were later labeled knowledge level; most items labeled procedural were later labeled comprehension level), the results of this process lent support to the validity of the WIKACFE instrument. See Appendix V for a summary of the experts' reviews.

Reliability refers to the extent which scores on a measurement instrument are the true scores of test takers. It is a measure of internal consistency and is often described as the reproducibility of test scores.

> Whenever a test is administered, the test user would like some assurance that the results could be replicated if the same individuals were tested again under similar circumstances. This desired consistency...is called *reliability*. (Crocker & Algina, 1986, p. 105)

In order to test the reliability of these instruments, a field test study was conducted. Two fifth-grade teachers from one school agreed to serve as the field test center. This school was different than those used in the study's sample. However, it was located in the same county and was comparable to the other schools used in this study.

One teacher had just completed the unit; hence, his students took only the posttest versions of both instruments. This teacher is henceforth referred to as the field-control teacher. The other teacher agreed to implement the unit using the experimental treatment approach. Her students were given the pretests prior to commencing the unit; posttests were administered at the completion of the unit. This teacher is henceforth referred to as the field-treatment teacher.

The researcher met with the field-treatment teacher at her school about one week prior to the commencement of the unit. The experimental treatment and other field testing procedures were described during this session. The researcher gave the field-treatment teacher a copy of the unit plan, treatment materials, and pretesting materials. The meeting served as an individualized workshop for the field test teacher.

For purposes of assessing the instrument, the researcher was present during the field test teachers' administration of the MyPOV pretests and the WIKACFE posttests. As soon as students completed the instruments, the teacher collected the instruments so students could not change their answers. Then, the teacher introduced the researcher who engaged students in a discussion about the tests.

The researcher gave students new copies of the instruments so they could refer to them during the discussion that ensued. The researcher posed the following questions to the students and encouraged their discussion:

1. Did you understand the instructions on the test? If not, what didn't you understand?
2. Did you have a difficult time responding to any statement/question? If yes, which ones and why?

In addition to interviewing the students, the researcher met individually with the teachers to discuss the tests, the test administration instructions, and the implementation of the treatment materials. The teachers shared ideas about ways to improve the treatment materials, tests, and test administration instructions. Based on the field test teachers' recommendations, students' comments, and the statistical analyses of students' tests, modifications were made to the tests and treatment materials. The items shown in appendices E, G, I, R, S, and X are the revised versions of items used in the study based on the results from field testing and the statistical analysis of the instruments (described next).

<u>Reliability of instrumentation</u>. Field test students' responses on both instruments were recorded on machine-readable forms and they were input to the mainframe computer at Virginia Tech using the optical scanner. Both tests were analyzed separately. Statistics were computed by the Virginia Tech Test Scoring Service. Reliability was estimated using the Kuder-Richardson Formula 20 (KR-20). Tables 3.5, 3.6, and 3.7 show general statistical results for the MyPOV instruments and the WIKACFE instrument. Due to the small sample size, the sub-categories of "Knowledge Items Only" and "Comprehension Items Only" were analyzed only on the posttest version of the WIKACFE instrument when both field test classes were included.

Table 3.5

General Statistical Results for MyPOV Instruments Used in the Field Test Study

Statistic	MyPOV Form A Pretest	MyPOV Form B Posttest
No. of Students	26	51
Mean No. Right[1]	15.31	14.33
Total No. Possible	20	20
Mean No. Omitted	.00	.02
Standard Deviation	2.414	3.984
Reliability Estimate (KR-20)	.649	.832
Standard Error of Measurement	1.431	1.632

[1] On the MyPOV instrument, high curiosity answers were scored as correct; low curiosity answers were scored as incorrect. Corrections were made for negatively worded items.

Table 3.6

General Statistical Results for WIKACFE Instrument Used in Field Test Study -- TOTAL TEST

Statistic	WIKACFE Pretest	WIKACFE Posttest
No. of Students	26	77
Mean No. Right	17.31	19.97
Total No. Possible	38	38
Mean No. Omitted	.12	.14
Standard Deviation	3.010	4.150
Reliability Estimate (KR-20)	.213	.573
Standard Error of Measurement	2.670	2.713

Table 3.7

General Statistical Results for Posttest Version of WIKACFE Instrument Used in Field Test Study -- KNOWLEDGE ITEMS ONLY[1] and COMPREHENSION ITEMS ONLY[2]

Statistic	Knowledge Items Only	Comprehension Items Only
No. of Students	77	77
Mean No. Right	15.44	4.53
Total No. Possible	30	8
Mean No. Omitted	.09	.05
Standard Deviation	3.473	1.382
Reliability Estimate (KR-20)	.510	.244
Standard Error of Measurement	2.431	1.202

[1] On the field test version of the WIKACFE (appendix W), knowledge items included all items except #9, #20, #27, #28, #29, #31, #37, and #38.

[2] On the field test version of the WIKACFE (appendix W), comprehension items included items #9, #20, #27, #28, #29, #31, #37, and #38.

As shown on Table 3.5, the reliability of the MyPOV instrument was adequate. The reliability of the WIKACFE instrument was low to adequate. Item discrimination indices were computed on all test analyses and they clearly showed that several items were not satisfactory on the WIKACFE instrument. It was expected that changing these test items would lead to greater test reliability.

For example, several items on the WIKACFE instrument had negative discrimination indices. This indicated that higher scoring students missed the right answer. These items were rewritten or revised, if possible.

With one exception, all items on the MyPOV instrument were maintained in the regular study as they appeared in the field test study. Students had great difficulty answering item number 20. Upon further analysis, the researcher determined that the item was too complex for students' ability level and the meaning of the statement changed greatly when the item was worded differently. Hence, the researcher decided to omit this item from all analyses even though it still appeared on the students' test form.

Items on the WIKACFE instrument which were found to be easy (more than 75% of the students answered correctly), were also eliminated, replaced, or revised. Likewise, incorrect response choices (called foils) on the WIKACFE which were not chosen by any students were either eliminated, replaced, or revised. The objective was to increase the spread of students' responses and to get responses on all foils.

The researcher proceeded to use the instruments in revised form for the present study. New reliability estimates were computed when the instruments were administered in the study; these reliability were expectedly higher and more acceptable. See Chapter 4 for a detailed analysis.

Summary

In this chapter, the methodology employed in this study was explained. The researcher explained how the experiment was organized and described how the instrumentation, unit plan, treatment group materials, and control group materials were developed and/or validated. Reliability estimates of .83 (MyPOV) and .57 (WIKACFE) were reported for the posttest versions of the instruments used in the field test study. Additionally, research hypotheses were identified and methods for analyzing them were shown.

Chapter Four

Findings

Introduction

The purpose of this study was to explore the effect of integrating technological activities with science instruction (called a science-technology linkage). The researcher examined whether students' achievement and curiosity relative to the unit of study were related to their participation in classes where the experimental treatment was employed. A secondary focus of the study was to determine whether students' curiosity about the unit topic prior to studying it was related to their achievement. The researcher used a quasi-experimental, pretest/posttest design for the study.

In this chapter, the findings in this study are shown in two sections. First, reliability data are reported for both of the instruments used in the study. Second, findings related to the hypotheses of this study are presented.

Instrumentation Reliability

Two instruments were developed for use in this study: 1). A measure of curiosity called, My Point of View (MyPOV), and 2). A measure of science knowledge relative to the unit studied called, What I Know About Changing Forms of Energy (WIKACFE). Each instrument was field tested to assess reliability and obtain item difficulty indices. Field test data were presented in Chapter 3; these were used to guide the researcher in making revisions of the instruments for use in the study. In this section, reliability data are reported for the revised instruments used in the study.

Students' responses were recorded on machine-readable forms and both sets of response forms were input to the mainframe computer at Virginia Tech using the optical scanner. Statistics were computed by the Virginia Tech Test Scoring Service. Both tests were analyzed separately. Reliability was estimated using Kuder-Richardson Formula 20 (KR-20).

My Point of View (MyPOV) Instruments. Two forms of this instrument were used in the study. Form A was the pretest version; form B was the posttest version. Item number 20 on each form of the MyPOV instrument was omitted from analysis which brought the highest score possible down from 20 to 19. This decision was made based on field test data and student interviews which indicated that this item was a poor discriminator of students' curiosity. This was probably due to the fact that the meaning of the statement changed when the item was reworded to make it acceptable for younger students. Table 4.1 shows general statistical results for both forms of the MyPOV instrument.

Table 4.1

General Statistical Results for MyPOV Instruments

Statistic	MyPOV Form A Pretest	MyPOV Form B Posttest
No. of Students	121	120
Mean No. Right[1]	13.75	13.99
Total No. Possible	19	19
Mean No. Omitted	.02	.01
Standard Deviation	3.731	4.333
Reliability Estimate (KR-20)	.799	.868
Standard Error of Measurement	1.671	1.572

[1] On the MyPOV instrument, high curiosity answers were scored as correct; low curiosity answers were scored as incorrect. Corrections were made for negatively worded items.

As shown in Table 4.1, the reliability estimates of both forms of the MyPOV instrument were moderately high. These figures are comparable to those reported for the field test versions.

<u>What I Know About Changing Forms of Energy Instrument.</u>

A singular instrument was used for measuring students' understanding of the science concepts relative to the unit studied. The pretest scores and posttest scores were analyzed in three separate ways: 1) Total test (all items), 2) Knowledge items only (items identified as measuring knowledge-level objectives), and 3) Comprehension items only (items identified as measuring comprehension-level objectives). See Appendix Z for a copy of the test and refer to Table 3.4 (page 98) to identify how individual test items were classified. Item #5 was omitted in all analyses because one of the test reviewers felt that the item could have more than one answer. Since the pretests were already given when this was determined, the researcher decided to eliminate the item from the analyses.

Tables 4.2, 4.3, and 4.4 show general statistical results for the three test analyses.

Table 4.2

General Statistical Results for WIKACFE Instrument --

TOTAL TEST

Statistic	WIKACFE Pretest	WIKACFE Posttest
No. of Students	119	119
Mean No. Right	19.20	26.21
Total No. Possible	37	37
Mean No. Omitted	.16	.14
Standard Deviation	4.702	5.994
Reliability Estimate (KR-20)	.665	.830
Standard Error of Measurement	2.720	2.469

Table 4.3

<u>**General Statistical Results for WIKACFE Instrument --**</u>

<u>**KNOWLEDGE ITEMS ONLY**</u>

Statistic	Knowledge Pretest	Knowledge Posttest
No. of Students	119	119
Mean No. Right	11.74	15.89
Total No. Possible	22	22
Mean No. Omitted	.12	.10
Standard Deviation	3.195	3.828
Reliability Estimate (KR-20)	.573	.762
Standard Error of Measurement	2.089	1.867

Table 4.4

General Statistical Results for WIKACFE Instrument --

COMPREHENSION ITEMS ONLY

Statistic	Comprehension Pretest	Comprehension Posttest
No. of Students	119	119
Mean No. Right	7.46	10.32
Total No. Possible	15	15
Mean No. Omitted	.04	.04
Standard Deviation	2.282	2.735
Reliability Estimate (KR-20)	.420	.655
Standard Error of Measurement	1.738	1.607

As shown in Tables 4.2, 4.3, and 4.4, the reliability estimates of all three forms of test analyses were adequate, particularly when the tests were administered after the science unit was completed. The Comprehension Item version shows the lowest reliability; however, this is not surprising since it had the lowest number of questions. Overall reliability for the entire test (37 items) increased from the field test version. This increase was expected due to the fact that individual test items were revised and improved based on field test data.

Findings Related to Hypotheses

The researcher used the SAS software package on the Virginia Tech mainframe computer to analyze data and compute descriptive and inferential statistics. A correlation matrix (Table 4.5) was developed for all the variables in the study. Partial correlation coefficients were computed to test hypothesis number 4 (Table 4.6). Analysis of covariance (ANCOVA) procedures were used to test all other research hypotheses. These procedures were useful since it was desired to increase the precision of the analysis by controlling for students' pretest scores on the MyPOV and WIKACFE instruments. The ANCOVA procedure was deemed acceptable for use with these data since they met the assumption of homogeneity of regression as measured with the

F-test. All hypotheses were tested at the .05 level of significance.

Table 4.5

Pearson Product Moment Correlation Coefficients and Number of Observations for all Variables

	1	2	3	4	5	6	7	8
PreCur (1)	1.000' 121	.581' 118	.014 119	.088 117	-.059 119	.063 117	.063 119	.093 117
PostCur (2)		1.000' 120	-.107 116	-.030 118	-.104 116	-.013 118	-.085 116	-.038 118
PreSci (3)			1.000' 115	.574' 119	.797' 115	.474' 119	.902' 119	.557' 115
PostSci (4)				1.000' 119	.406' 115	.877' 119	.556' 115	.939' 119
PreComp (5)					1.000' 119	.422' 115	.459' 119	.333' 115
PostComp (6)						1.000' 119	.399' 115	.659' 119
PreKnow (7)							1.000' 119	.582' 115
PostKnow (8)								1.000' 119

' = $p < .05$

Note: Number of observations vary (bottom number in each cell) because individual students' scores were dropped from analysis if they did not take both the pretest and the posttest of a particular test (i.e., MyPOV or WIKACFE).

PreCur = Curiosity Pretest Score
PostCur = Curiosity Posttest Score
PreSci = Overall Science Pretest Score
PostSci = Overall Science Posttest Score
PreKnow = Science Knowledge Pretest Score
PostKnow= Science Knowledge Posttest Score
PreComp = Science Comprehension Pretest Score
PostComp= Science Comprehension Posttest Score

Table 4.6

Partial Correlation Coefficients for Selected Variables

Correlated Variables	Variable Partialed Out	Partial Correlation Coefficient	Prob
PreCur x PostSci	PreSci	.0978	.150
PreCur x PostKnow	PreKnow	.0695	.231
PreCur x PostComp	PreComp	.0972	.152

_n_ = 112

PreCur = Curiosity Pretest Score
PreSci = Overall Science Pretest Score
PostSci = Overall Science Posttest Score
PreKnow = Science Knowledge Pretest Score
PostKnow= Science Knowledge Posttest Score
PreComp = Science Comprehension Pretest Score
PostComp= Science Comprehension Posttest Score

Students' Science Achievement. All students involved in this study were administered the WIKACFE instrument as a pretest and posttest. Tables 4.7 and 4.8 display the means and standard deviations for pretests and posttests by group and gender. Tables 4.9 and 4.10 report means and standard deviations by group for girls only.

Table 4.7

Pretest Means and Standard Deviations for Overall Science, Science Knowledge, and Science Comprehension by Group and Gender

		Overall		Knowledge		Comprehension	
Group/ Gender	n	Mean	SD	Mean	SD	Mean	SD
Treatment	55	19.56	5.22	12.09	3.56	7.47	2.38
Control	64	18.89	4.27	11.44	2.87	7.45	2.23
Boys	57	19.74	5.00	12.05	3.29	7.68	2.35
Girls	62	18.71	4.43	11.45	3.14	7.26	2.23

Table 4.8

Posttest Means and Standard Deviations for Overall Science, Science Knowledge, and Science Comprehension by Group and Gender

		Overall		Knowledge		Comprehension	
Group/ Gender	*n*	Mean	SD	Mean	SD	Mean	SD
Treatment	56	25.93	6.41	15.71	4.04	10.21	2.92
Control	63	26.46	5.69	16.05	3.69	10.41	2.60
Boys	59	27.15	5.77	16.66	3.59	10.49	2.84
Girls	60	25.28	6.16	15.13	3.96	10.15	2.67

Table 4.9

Girls' Pretest Means and Standard Deviations for Overall Science Score, Science Knowledge Score, and Science Comprehension Score by Group

		Overall		Knowledge		Comprehension	
Group	n	Mean	SD	Mean	SD	Mean	SD
Treatment	33	18.33	4.71	11.30	3.35	7.03	2.14
Control	29	19.14	4.14	11.62	2.92	7.52	2.34

Table 4.10

Girls' Posttest Means and Standard Deviations for Overall Science Score, Science Knowledge Score, and Science Comprehension Score by Group

		Overall		Knowledge		Comprehension	
Group	n	Mean	SD	Mean	SD	Mean	SD
Treatment	32	24.59	6.94	14.78	4.37	9.81	2.97
Control	28	26.07	5.14	15.54	3.47	10.54	2.27

These data were subjected to three separate analyses of covariance in order to test the hypotheses stated for this study. Tables 4.11, 4.12, and 4.13 display the results of the analyses of covariance for the total group (boys and girls combined). Tables 4.14, 4.15, and 4.16 display the results of the analyses of covariance for girls only. Least squares means and standard errors for all analyses (i.e., when students' pretest scores are used as the covariates) are reported in tables 4.17 and 4.18. Test scores for students who were absent on the day one of the tests were administered were omitted from analysis. Students' posttest scores served as the dependent variable in this analysis; students' pretest scores on the WIKACFE instrument were used as covariates in the analysis.

Table 4.11

Analysis of Covariance for Students' Overall Science Achievement by Group and Gender

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Science	1	1220.127	49.58	.0001'
Group	1	13.719	.56	.4569
Gender	1	32.647	1.33	.2519
Group*Gender	1	0.549	.02	.8815
Error	110	2707.003		
Total (Adj.)	114	4115.130		

' = $p < .05$

$\underline{n}$ = 115

Pre-Science = Students' Science Pretest Score (Total test)

Note: Least Squares Means shown on Table 4.17.

Table 4.12

Analysis of Covariance for Students' Science Knowledge Achievement by Group and Gender

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Knowledge	1	533.894	54.82	.0001'
Group	1	12.238	1.26	.2647
Gender	1	30.519	3.13	.0795
Group*Gender	1	0.113	.01	.9145
Error	110	1071.338		
Total (Adj.)	114	1697.791		

' = $p < .05$

n = 115

Pre-Knowledge = Students' Science Knowledge Pretest Score

Note: Least Squares Means shown on Table 4.17.

Table 4.13

Analysis of Covariance for Students' Science Comprehension Achievement by Group and Gender

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Comp	1	134.857	21.37	.0001*
Group	1	0.033	.01	.9424
Gender	1	.904	.14	.7059
Group*Gender	1	4.525	.72	.3990
Error	110	694.258		
Total (Adj.)	114	851.096		

* = $p < .05$

n = 115

Pre-Comp = Students' Science Comprehension Pretest Score

Note: Least Squares Means shown on Table 4.17.

Table 4.14

Analysis of Covariance for Girls' Overall Science Achievement by Group

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Science	1	574.608	21.18	.0001'
Group	1	9.848	.36	.5493
Error	56	1519.185		
Total (Adj.)	58	2142.169		

' = $p < .05$

$\underline{n}$ = 59

Pre-Science = Girls' Science Pretest Score (Total test)

Note: Least Squares Means shown on Table 4.18.

Table 4.15

Analysis of Covariance for Girls' Science Knowledge Achievement by Group

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Knowledge	1	319.276	32.09	.0001'
Group	1	4.823	.48	.4892
Error	56	557.236		
Total (Adj.)	58	889.932		

' = $p < .05$

$\underline{n} = 59$

Pre-Knowledge = Girls' Science Knowledge Pretest Score

Note: Least Squares Means shown on Table 4.18.

Table 4.16

Analysis of Covariance for Girls' Science Comprehension Achievement by Group

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Comp	1	35.928	5.62	.0212'
Group	1	4.141	.65	.4242
Error	56	357.810		
Total (Adj.)	58	404.576		

' = $p < .05$

$\underline{n} = 59$

Pre-Comp = Girls' Science Comprehension Pretest Score

Note: Least Squares Means shown on Table 4.18.

Table 4.17

Least Squares Means and Standard Errors[1] for Students' Overall Science Score, Science Knowledge Score, and Science Comprehension Score, and Curiosity by Group and Gender

	GROUP		GENDER	
	Treatment	Control	Boys	Girls
Overall Science	25.73 (0.69)	26.43 (0.63)	26.63 (0.68)	25.54 (0.65)
Science Knowledge	15.46 (0.44)	16.13 (0.40)	16.32 (0.43)	15.27 (0.41)
Science Comprehension	10.29 (0.35)	10.32 (0.32)	10.40 (0.35)	10.22 (0.33)
Curiosity	14.68 (0.49)	13.28 (0.45)	13.94 (0.49)	14.03 (0.46)

Note: Higher curiosity scores indicate higher curiosity.

[1] Standard errors shown in parentheses.

Table 4.18

Least Squares Means and Standard Errors[1] for Girls' Overall Science Score, Science Knowledge Score, and Science Comprehension Score, and Curiosity by Group

	GROUP	
	Treatment	Control
Overall Science	24.726 (0.941)	25.554 (0.991)
Science Knowledge	14.761 (0.567)	15.336 (0.597)
Science Comprehension	9.828 (0.458)	10.369 (0.483)
Curiosity	14.648 (0.654)	12.642 (0.721)

Note: Higher curiosity scores indicate higher curiosity.

[1] Standard errors shown in parentheses.

Students' Curiosity. The MyPOV instrument was administered to all students in this study as a pretest (form A) and posttest (form B). Table 4.19 displays the means and standard deviations for pretests and posttests by group and gender. Table 4.20 displays the means and standard deviations by group for girls only. ANCOVA procedures were used to analyze these data; findings are presented in tables 4.21 and 4.22. Again, scores for students who were absent on the day one form of the test was administered (i.e., form A or form B) were omitted from analysis. Students' scores on form B of this test served as the dependent variable in this analysis; students' scores on form A of the MyPOV instrument were used as covariates in the analysis.

Table 4.19

Means and Standard Deviations for Students' Curiosity by Group and Gender

	Pretest (Form A)			Posttest (Form B)		
Group/Gender	n	Mean	SD	n	Mean	SD
Treatment	56	13.95	3.68	58	14.84	3.32
Control	65	13.58	3.83	62	13.19	5.03
Boys	58	14.36	3.81	58	14.26	3.88
Girls	63	13.19	3.63	62	13.74	4.77

Note: A higher score indicates higher curiosity.

Table 4.20

Girls' Curiosity Means and Standard Deviations by Group

	Pretest (Form A)			Posttest (Form B)		
Group	n	Mean	SD	n	Mean	SD
Treatment	34	13.65	3.53	34	15.00	3.13
Control	29	12.66	3.73	28	12.21	5.91

Note: A higher score indicates higher curiosity.

Table 4.21

Analysis of Covariance for Students' Curiosity by Group and Gender

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Curiosity	1	700.602	55.89	.0001'
Group	1	55.193	4.40	.0381'
Gender	1	0.228	0.02	.8930
Group*Gender	1	13.300	1.06	.3052
Error	113	1416.476		
Total (Adj.)	117	2252.000		

' = $p < .05$

$\underline{n}$ = 118

Pre-Curiosity = Students' Curiosity Pretest Score

Note: Least Squares Means shown on Table 4.17.

Table 4.22

Analysis of Covariance for Girls' Curiosity by Group

Source of Variation	df	Sum of Squares	F	Prob > F
Pre-Curiosity	1	418.356	29.09	.0001'
Group	1	60.392	4.20	.0449'
Error	59	848.359		
Total (Adj.)	61	1385.871		

' = $p < .05$

$\underline{n}$ = 62

Pre-Curiosity = Girls' Curiosity Pretest Score

Note: Least Squares Means shown on Table 4.18.

Eight hypotheses were stated prior to commencing this study. Each of these hypotheses are presented again here with their relative findings.

<u>Hypothesis 1</u>. The hypothesis was stated as:

> *Students studying a science unit accompanied by technological activities (treatment group) will have higher overall achievement levels than students studying the unit without technological activities (control group), controlling for prior overall science knowledge and comprehension.*

Based on the data as shown in Table 4.11, this hypothesis was **not supported** (F=.56; p=.4569). After controlling for prior overall science knowledge and comprehension, treatment group students' mean achievement (25.73) was not significantly different than control group students' mean achievement (26.43).

<u>Hypothesis 2</u>. The hypothesis was stated as:

> *Students studying a science unit accompanied by technological activities (treatment group) will have higher science comprehension achievement levels than students studying the unit without*

technological activities (control group), controlling for prior science comprehension.

Based on the data as shown in Table 4.13, this hypothesis was **not supported** (F=.01; p=.9424). After controlling for prior science comprehension, treatment group students' mean science comprehension achievement (10.29) was not significantly different than control group students' mean science comprehension achievement (10.32).

Hypothesis 3. The hypothesis was stated as:

There will be no difference between treatment group students' and control group students' science knowledge achievement, controlling for prior science knowledge.

Based on the data as shown in Table 4.12, this hypothesis was **supported** (F=1.26; p=.2647). After controlling for prior science knowledge, treatment group students' mean science knowledge achievement (15.46) was not significantly different than control group students' mean science knowledge achievement (16.13).

Hypothesis 4. The hypothesis was stated as:

Higher curiosity students (before the unit) will have higher overall science *achievement levels than lower curiosity students (before the unit), controlling for prior overall science knowledge and comprehension.*

Based on the partial correlation coefficients (Table 4.6), this hypothesis was **not supported**. There was no significant relationship between students' prior curiosity and their science achievement when controlling for their science pretest scores. This was the case in all instances when students' pre-curiosity was correlated with their scores on the science posttests (overall, knowledge-only, and comprehension-only). Since there was no significant relationship, the curiosity scores were not factored into any of the analyses of covariance.

Hypothesis 5. The hypothesis was stated as:

Students studying a science unit accompanied by technological activities (treatment group) will become more curious about the unit topic than students studying the unit without technological activities (control group), controlling for prior curiosity.

Based on the data as shown in Table 4.21, this hypothesis was **supported** ($F=4.40$; $p=.0381$). After controlling for prior curiosity, treatment group students' mean curiosity (14.68) was significantly higher than control group students' mean curiosity (13.28).

Hypothesis 6. The hypothesis was stated as:

There will be no difference between boys and girls overall science achievement levels, controlling for prior overall science knowledge and comprehension.

Based on the data as shown in Table 4.11, this hypothesis was **supported** (F=1.33; p=.2519). After controlling for prior overall science knowledge and comprehension, boys' mean achievement (26.63) was not significantly different than girls' mean achievement (25.54). Findings were comparable when boys' and girls' mean achievement was analyzed and compared for knowledge-only science items (F=3.13; p=.0795) and comprehension-only science items (F=.14; p=.7059). These data are presented on tables 4.12 and 4.13, respectively.

Hypothesis 7. The hypothesis was stated as:

Girls studying a science unit accompanied by technological activities (girls in treatment group) will have higher science knowledge and science comprehension achievement levels than *girls studying the unit without technological activities (girls in control group), controlling for girls' prior science knowledge and comprehension.*

Based on the data as shown in Tables 4.14, 4.15, and 4.16, this hypothesis was **not supported**. When controlling for girls' prior science knowledge and comprehension, treatment group girls' mean achievement was not significantly different than control group girls' mean achievement. Findings were comparable when girls' mean achievement was analyzed and compared for overall science ($F=.36$; $p=.5493$), knowledge-only science items ($F=.48$; $p=.4892$), and comprehension-only science items ($F=.65$; $p=.4242$).

Hypothesis 8. The hypothesis was stated as:

Girls studying a science unit accompanied by technological activities (treatment group girls) will become more curious about the unit topic than girls studying the unit without technological activities (control group girls), controlling for girls' prior curiosity.

Based on the data as shown in Table 4.22, this hypothesis was **supported** (F=4.20; p=.0449). After controlling for prior curiosity, treatment group girls' mean curiosity (14.65) was significantly higher than control group girls' mean curiosity (12.64).

Summary

This chapter presented the results of the study in two sections. First, reliability data were reported for both of the instruments used in the study. Second, findings related to the hypotheses of this study were presented.

Results of the instrumentation analyses revealed that the curiosity instrument (My Point of View [MyPOV]) and the science instrument (What I Know About Changing Forms of Energy [WIKACFE]) were acceptably reliable. Estimated reliability on the posttest version of the MyPOV was .868. Estimated reliability on the posttest versions of the WIKACFE were .655 to .830.

The results of the Pearson product moment correlation analysis and the analyses of covariance for students' science achievement and curiosity relative to the unit of study were reported. Pretest and posttest means and standard deviations, as well as least squares means and standard errors, were also shown.

Findings relative to each hypothesis proposed for the study were presented. It was reported that students' science achievement was not significantly different between the treatment group and the control group. The findings were comparable for three separate analyses of the WIKACFE (total test, knowledge items only, and comprehension items only). Similar results were found when girls' scores were analyzed separately.

The results of the study provide evidence that there was a significant group effect on students' curiosity which favored the treatment group students. Treatment group students had significantly higher curiosity scores than control group students. The pattern was similar and significant when girls were analyzed separately.

Chapter Five

Conclusions and Recommendations

Introduction

This chapter begins with a summary of the study and a review of the findings. It is followed by a discussion of the conclusions drawn from the findings and closes with implications and recommendations for further research.

Summary of the Study

The purpose of this study was to explore the effect of integrating technological activities with science instruction (called a science-technology linkage). The researcher examined whether fifth-grade students' science achievement and curiosity relative to a unit of study in science were related to their participation in classes where the experimental treatment was employed. A secondary focus of the study was to determine whether students' curiosity about the unit topic prior to studying it was related to their achievement. The unit topic chosen for this study was drawn from the physical science section of the textbook used in participating schools. It was titled, "Changing Forms of Energy."

The researcher used a quasi-experimental, pretest/posttest design for the study. Two separate instruments were used to collect data: 1) a measure of students' curiosity relative to the unit studied, and 2) a measure of students' knowledge and comprehension of the science concepts relative to the unit studied. Both instruments were developed by the researcher and field tested with fifth-grade students prior to conducting the study.

The sample used in this study was drawn from a population of fifth-grade students in Staunton and Augusta County, Virginia. Students were drawn from two separate school districts within this region; 123 students participated in the study.

Six fifth-grade classroom teachers participated in the study. Classrooms were randomly assigned as treatment and control groups. Both groups of teachers were provided with lesson plans and materials to implement the unit per a prescribed plan. Treatment group teachers integrated two technological activities (i.e., hands-on, technological problem-solving activities for students) with their units; control group teachers taught the unit using traditional science methods (i.e., teacher demonstrations as prescribed by textbook). The treatment approach was drawn from Mission 21, an experimental technology education program developed and field tested in Virginia (Brusic & Barnes, 1992). Teachers implemented the 10-day unit during a similar time frame in April 1991.

Eight hypotheses were stated prior to conducting the study. Analysis of covariance served as the primary means of analyzing the data relative to the hypotheses. Students' pretest scores served as the covariates in these analyses.

The findings of the study are summarized as follows:

1. There was no significant difference between treatment group students' science achievement and control group students' science achievement when students' pretest scores were used to control for prior knowledge. This was the case in three separate analyses of students' scores: 1) total test score, 2) items measuring knowledge-level objectives only, and 3) items measuring comprehension-level objectives only. This finding was consistent with an analysis conducted on girls' scores only and when girls' scores were compared with boys' scores.
2. There was a significant difference between treatment group students' curiosity and control group students' curiosity at the conclusion of the unit, controlling for prior curiosity. The difference favored the treatment group. When girls' scores were analyzed separately from the total group, the difference remained significant beyond the .05 alpha level.

3. There was no significant relationship between students' prior curiosity and their achievement when controlling for their prior science knowledge and comprehension.

Conclusions

Based on the findings in this study, the researcher concludes that the integration of technological activities with science instruction (i.e., the science-technology linkage) may positively affect fifth-grade students' curiosity but may not enhance or deter from their science achievement. Hence, the science-technology linkage shows promise as a useful method of promoting greater student curiosity without negatively affecting their achievement.

This conclusion is consistent with studies conducted by Gerne (1968) and Pershern (1967) which featured similar industrial arts-type approaches to teaching science as compared to traditional science methods (textbook-based). Both researchers found that students' achievement scores were not significantly different between treatment and control groups but that their scores on attitude questionnaires were, favoring the treatment group approach.

In addition, these findings support previous research by Glasson (1989) and Tobin (1988) which suggested that there may not be differential effects on students' science achievement when only lower levels of understanding are measured. Both Glasson and Tobin examined achievement differences relative to declarative and procedural knowledge. They did not find significant differences in students' declarative knowledge achievement when activity-based science programs were used. Declarative knowledge achievement is comparable to the knowledge and comprehension achievement referred to in this study.

However, the findings in this study are not consistent with some of the findings from other science achievement studies which found that hands-on (industrial arts-type) learning techniques enhanced students' science learning (i.e., Downs, 1969; Logan, 1973). Moreover, the findings from this study differ from related studies in science education which show considerable support for activity-based science instruction as a means of enhancing students' science achievement (Bredderman, 1982, 1985; Mullis & Jenkins, 1988; Saunders & Shepardson, 1987; Shymansky et al., 1983).

These findings may be attributable to several factors. First, the achievement test developed for this study was rather limited. It was completely science-focused and lacked any questions pertaining to technological understanding. Further, it did not include higher level questions that assessed problem-solving ability. It is likely that the instrument did not accurately measure the additional things that students may have learned through the problem-solving, technological activities.

Second, the WIKACFE instrument was subjected to a minimal amount of reliability and validity assessment. It is possible that the instrument was not as reliable and valid of a measure of students' knowledge and comprehension of the science content as was expected.

The third explanation relates to a factor of external validity in this study -- reactivity. Despite the researcher's attempts to control reactivity, it is possible that it occurred with teachers more than with students. The researcher provided treatment group and control group teachers with all the lessons and materials they needed to implement the unit. All teachers (treatment and control) remarked to the researcher on numerous occasions that it was "wonderful" to be handed everything they needed to teach the unit. Teachers' unusual enthusiasm and exceptional preparedness for this unit (because they knew they were part of a study and all lessons and materials were provided to them) may have significantly affected their delivery of the unit. While it is assumed that reactivity had equal effects across groups, the researcher suspects that control group teachers did not want to "look bad" when the results were tabulated. In turn, they may have drilled students in preparation for the tests beyond what is reasonable and expected.

The findings in this study with regard to the curiosity variable were both surprising and expected. It was surprising that there were no significant correlations between students' curiosity scores and achievement scores. Previous research in this area showed great support for curiosity as a factor in student learning (Berlyne, 1954b, 1966; Day, 1968; Maw & Maw, 1961b, 1964; Paradowski, 1967). This incongruity may be due to the fact that the present study focused on state or specific curiosity (relative to a certain science unit) whereas the other researchers assessed trait or diversive curiosity (a personality characteristic which is exhibited more habitually). Research related to state curiosity and achievement is scant.

As expected, the treatment group students significantly increased their curiosity scores as compared to the control group students. This was the case when scores were analyzed as a total group (boys and girls together) and when girls were analyzed separately. This finding is consistent with educational theorists' claims that meaningful and relevant educational experiences will enhance students' interest (Dewey, 1917, 1963, 1969; Donaldson & Vinson, 1979; Kolb 1984). Students' interest is considered to be a component of their curiosity.

The finding that treatment group students' curiosity was enhanced may be especially useful in light of the fact that findings from some studies suggest that students' interest in science decreases as they stay in school (Mullis & Jenkins, 1988). If the science-technology linkage can promote curiosity (which includes interest), then it serves a valuable function in the curriculum. It may help to reverse the trend toward decreasing science interests as students progress through school.

This study also found significant group differences between girls' curiosity. This is notable since previous studies with regard to girls' interest in science show that girls are less interested in the physical sciences than other areas of science such as life sciences (Mullis & Jenkins, 1988; Smail & Kelly, 1984b). If science-technology linkages can positively influence girls' attitudes to physical science, then they make a significant contribution to girls' experiences in science.

Implications and Recommendations

The findings in this study have implications to technology education and science education. Foremost, they show initial evidence of the value of science-technology linkages toward enhancing boys' and girls' specific curiosity. Additionally, the findings from this study which conflict with previous achievement studies pose a challenge to educators to more fully assess the educational value of experiential learning activities such as those associated with technology education.

To aid further research attempts, the following recommendations are proposed:

1. There is a dire need for reliable and valid measures of elementary students' curiosity about, and understanding of, science and technology. Researchers are encouraged to conduct extensive developmental studies for the sole purpose of creating and validating these instruments.
2. There is a dearth of research in technology education which focuses on the constitution of technological knowledge or technological understanding as compared to scientific knowledge and understanding. This is the primary reason why this component was absent from the present study. Additional research is necessary in this area to lay the foundation for the development of valid and reliable instruments which detect students' development in this area.
3. In order to verify the findings from this study and make the findings more generalizable, this study should be replicated in other schools in the same

region and in new regions at the fifth-grade level.

4. New studies should be designed and conducted which further explore the effect of integrating technological activities with science instruction (science-technology linkages). These studies should be implemented in a variety of grade levels, in different geographical locations, and with other science units and corresponding technological activities.
5. Extensive research is needed to determine the complete educational value of integrating technological activities with all subject areas at the elementary level. Further studies are needed which assess the contributions of these experiences to students' affective, cognitive, and psychomotor development.
6. Instrumentation was a major limiting factor in this study with regard to measuring students' curiosity and achievement. Researchers should give greater consideration to the use of qualitative studies which have the flexibility to recognize and record subtle differences, unique student ideas and concepts of science and technology, and other qualities which were impossible to capture with standardized instruments.

7. It is difficult to generalize about the findings from this study since it was of such limited size and length. New studies are needed which compare the effectiveness of the experimental treatment over longer periods of time and with a greater number of students. Longitudinal studies which involve students with the experimental treatment over the course of several semesters or years may provide a more valid and reliable picture of the value of science-technology linkages.

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Appendix A

Itemized Summary of Procedures Followed in Conducting the Study

TIMELINE FOLLOWED
FOR CONDUCTING THE STUDY

NO.	TASK	START DATE	FINISH DATE
1	Write chapters 1-3 of dissertation	8/90	1/14/90
2	Write and send proposal to school district administrators summarizing the study and specifying involvement of school personnel.	10/90	11/15/90
3	Discuss details of research project with school district personnel, seek their approval, and identify potential teachers.	11/15/90	1/04/91
4	Generate draft of curiosity instruments.	1/03/91	2/01/91
5	Meet with prospective teachers to clarify their role in the study, verify their involvement, and identify potential unit topics for the study.	1/04/91	1/09/91
6	Get consensus on one unit topic to be used in the study and verify the consensus by letter	1/04/91	1/11/91

NO.	TASK	START DATE	FINISH DATE
	to all teachers.		
7	Generate a draft unit plan and disseminate to all teachers.	1/7/91	1/21/91
8	Generate draft of the science test.	1/07/91	2/01/91
9	Develop an appropriate technological activity to correlate with chosen unit.	1/7/91	1/30/91
10	Prospectus examination. (Defend chapters 1-3)		1/14/91
11	Collect information from all teachers regarding content of unit.	1/18/91	1/18/91
12	Identify panel of experts to evaluate the curiosity instruments and science test.	1/20/91	1/30/91
13	Collect feedback from all teachers regarding acceptability of unit plan. Make modifications as needed.	1/21/91	1/28/91
14	Randomly determine treatment group and control group teachers. Write a letter to each teacher identifying his/her role.		1/28/91

NO.	TASK	START DATE	FINISH DATE
15	Send or deliver instruments and sample technological activities to panel of experts for review.	2/04/91	2/04/91
16	Collect input from panel of experts. Make modifications as needed.	2/11/91	2/15/91
17	Meet with Mission 21 project staff to share the technological activity and seek their approval for its use.		2/12/91
18	Meet with field test teacher to inservice her on how to implement the unit.		2/18/91
19	Administer curiosity instruments to field test groups. Discuss the test with students to identify confusing statements or unclear instructions.		2/27/91
20	Administer science test to field test group. Discuss the test with students to identify confusing questions or unclear instructions.		2/27/91
21	Begin field testing the unit.		2/28/91

NO.	TASK	START DATE	FINISH DATE
22	Set date for treatment group workshop.		3/04/91
23	Meet with all control group teachers to explain how to implement unit and administer instruments. Deliver all materials needed to teach unit.	3/08/91	3/30/91
24	Meet with field test teacher to discuss his/her experience with implementing the unit using experimental treatment.		3/19/91
25	Analyze reliability of both instruments using field test data. Modify instruments based on statistical analysis, class interview, teacher interview, and experts' assistance.	3/19/91	3/25/91
26	Conduct treatment group workshop. Disseminate unit plan and all treatment materials.		3/25/91
27	Deliver all pretests to schools.	4/03/91	4/09/91
28	Study begins in schools.	4/04/91	4/12/91
29	Collect all pretest data from schools.	4/05/91	4/16/91
30	Analyze pretest data.	4/16/91	4/24/91

NO.	TASK	START DATE	FINISH DATE
31	Deliver all posttests to schools.	4/17/91	4/24/91
32	Study concludes in schools.	4/23/91	5/01/91
33	Collect all posttest data and related materials (i.e., daily plans, materials) from schools.	4/24/91	5/01/91
34	Analyze all data.	5/01/91	5/22/91
35	Write chapters 4 and 5 of dissertation.	5/22/91	7/15/91
36	Send thank you letters to all teachers with data for their students.		5/24/91
37	Final Defense. (Defend dissertation.)		7/15/91

Appendix B

<u>Letter to Teachers Verifying Unit Topic and Time Frame</u>

January 9, 1991

Teacher's Name
School
Street Address
City, VA Zip

Dear First Name:

As of this week, I was finally able to make contact with all teachers who will be involved in the study that I will be conducting. Eight classroom teachers will be involved in the study in Staunton City Schools and Augusta County Schools. Based on my conversation with each teacher, I believe that I have reached agreement on the following items.

Unit to be taught	**Changing Forms of Energy** (Chapter 7 of science textbook; Focus only on lessons 1, 2, and 3 in this chapter)
Approx. Date to begin unit	**As soon as possible after spring break** (Between April 3-15)
Time of day to teach unit	**Start class some time between 1:00-1:30**
Unit specifi-cations	Teach unit for **30-35 minutes per day**. Unit will last about **10 school days**.

I will be developing the unit plan during the next few weeks based on the information provided in the textbook (teacher's edition), other relevant content books (like library books), and information provided by each of the eight classroom teachers. If you have information (i.e., previously used lesson plans, unit plan, handouts) that you think would help me do this, please collect these items. I will visit the main office in your school on **January 18** to pick-up these items. Please leave the items with the office staff so I won't need to bother you during class time. I will only visit your school on that day if you indicate on the enclosed postcard that you have items for me. Any items you lend will be returned; only items *other than textbook material* need to be submitted.

Enclosed with this letter is a pre-addressed, postage-paid postcard. Please fill-out the information on the back of the card indicating your agreement to the above information and your desire to contribute information to the development of the unit plan. Drop the card in the mail as soon as possible.

Thank you for your agreeing to participate in this study. If you ever have any questions or concerns about the study, please feel free to contact me.

Sincerely,

Sharon A. Brusic
Researcher

Enclosure: postcard

Appendix C

Unit Plan
(Revised Version as Used in Study)

SCIENCE UNIT PLAN

Unit Theme	Changing Forms of Energy
Unit Topics	1. How does energy change forms? 2. How is electric energy produced? 3. How is electric energy changed and used?
Total Time for Unit	Approximately 300-350 minutes
Homework	None
Date of Implementation	Begin implementation between 4/3/91 and 4/15/91
Time of Implementation	Begin class any time between 1:00-1:30
Number of class periods	About 10. This does not include pretesting and posttesting
Length of class periods	30-35 minutes
Textbook Reference	Discover Science, level 5, 1989, published by Scott Foresman Company, pp. 180-197
Comments to Teacher	The following outline was derived from the textbook reference. Each major concept (identified with Roman numeral) is referenced with appropriate page numbers from the student text.

Unit Concepts

HOW DOES ENERGY CHANGE FORMS?

I. Work happens only when energy is used to move an object.

(pp. 181–182)

A. No work is done if a ball rolls and does not move another object.

B. Work is done if the rolling ball knocks over a lamp.

II. There are six forms of energy.

(pp. 183–184)

A. Mechanical energy: energy that moves objects.

1. A hammer driving a nail into a board has mechanical energy.
2. A rolling ball has mechanical energy.

B. Thermal energy: energy of the movement of the particles that form an object.

1. Warm skin has much thermal energy.
2. Cool water has less thermal energy.

C. Electric energy: energy carried by electricity.

1. Power lines carry electric energy.
2. Appliance cords carry electric energy.

D. Radiant energy: energy that can flow through empty space.

1. Sunlight
2. Radio waves
3. X rays

E. Chemical energy: energy released by chemical changes.

1. Gasoline
2. Coal

F. Nuclear energy: energy released when nuclei of atoms split or join.

1. Stars shine because they release nuclear energy.
2. The sun produces energy through nuclear fusion.

III. Mechanical Energy is energy that can move objects.
(p. 183)

A. It can be potential energy (stored energy), like:
   1. A ball at the top of steps
   2. A windup toy that is wound, but not yet released

B. In can be kinetic energy (motion energy), like:
   1. A ball rolling down the steps
   2. A windup toy that is released and moving on its own
   3. High winds
   4. Moving water, as in a river or stream
   5. A sled speeding down a hill

IV. Mechanical energy can be increased or decreased.
(p. 183)

A. Potential mechanical energy can be increased or decreased.
   1. Moving the ball to a higher step increases its potential mechanical energy.
   2. Moving the ball to a lower step decreases its potential mechanical energy.

B. Kinetic mechanical energy can be increased or decreased.
   1. Moving the ball faster increases its kinetic mechanical energy.
   2. Moving the ball slower decreases its kinetic mechanical energy.
   3. The faster a hammer is moving when it hits the nail, the farther the nail will go into the board.

V. Any form of energy can change into another form of energy.
(pp. 182-187)

A. Potential energy can change to kinetic energy (i.e., the ball had potential energy when it sat atop the stairs and it changed to kinetic energy when the ball rolled down the stairs).

B. Kinetic energy can change to potential energy (i.e., you can wind up a toy [kinetic energy] and then hold it there without releasing the knob [potential energy].

C. Radiant energy can be changed into chemical energy (i.e., plants change radiant energy from sunlight into chemical energy, which they store as sugar).
D. Chemical energy can be changed into mechanical energy (i.e., people change chemical energy from food into mechanical energy when they move).
E. Mechanical energy can be changed into electrical energy (i.e., mechanical energy of steam moves a turbine at a power plant which produces electrical energy).

VI. **Changing energy from one form to another is useful.**
(p. 185)
A. We get electricity to light our homes this way.
B. We can heat our homes and schools this way.
C. We can process our foods this way.

VII. **Matter can change to energy and energy can change to matter, but they never disappear.**
(p. 186)

<u>HOW IS ELECTRIC ENERGY PRODUCED?</u>

I. **Atoms are made of protons, neutrons, and electrons.**
(p. 188)
A. A proton has a positive electric charge.
B. A neutron has no electric charge.
C. An electron has a negative electric charge.
D. Atoms hold their protons and neutrons tightly.
E. Electrons can move freely.

II. **Sometimes an atom loses electrons and sometimes it gains electrons which determines how an atom is charged.**
(pp. 188-89)
A. An atom is negatively charged if it has more electrons than protons.
B. An atom is positively charged if it has more protons than electrons.

III. **Electric force is the pulling together and pushing away of atoms and objects.**
(pp. 188-89, 193)
A. Oppositely charged atoms and objects pull together.
B. Atoms and objects with like charges push away from each other.

IV. Electricity is caused by the movement of electrons.
(pp. 189, 193)

A. Rubbing two objects together can cause electrons to move from one object to the other causing electricity.

B. Electrons move in two different ways.

1. They can jump through the air from one object to another causing a spark of electricity.
2. They can flow which makes an electric current.

V. People can control and use electric current using conductors and insulators.
(p. 190)

A. Conductors are matter, like metals, which allow electric current to easily flow through them.

B. Insulators are matter, like rubber, glass, and plastic, which do not allow electric current to easily flow through them.

VI. Batteries and generators change other forms of energy to electric energy and then push the electrons.
(pp. 190-91)

A. A dry cell battery (like a flashlight battery) changes chemical energy to electric energy in a nonliquid (paste) material.

B. A wet cell battery (like a car battery) changes chemical energy to electric energy in a liquid.

C. An electric generator is a device that uses a magnet to change mechanical energy into electricity.

VII. Closed circuits are paths of electric current which have three main parts.
(p. 190)

A. A battery or generator pushes electrons.

B. Wires carry the current.

C. Some object, like a bulb, uses the current.

VIII. A circuit must be closed in order for current to flow through it.
(p. 192)

A. A switch controls electricity by opening and closing the circuit.

B. When the switch closes the circuit (makes the circuit complete), current can flow. The device will work.

C. When the switch opens the circuit (has a break in it), current cannot flow. The device will not work.

HOW IS ELECTRIC ENERGY CHANGED AND USED?

I. Many useful objects change electric energy into other forms of energy.
(pp. 194-95)
  A. A toaster changes electric energy to thermal energy and then to radiant energy.
  B. An electric stove changes electric energy to thermal energy.
  C. A light bulb changes electric energy to radiant energy.
  D. Electric motors change electric energy to mechanical energy.

II. Electric power is the amount of energy used in a certain amount of time.
(pp. 195-96)
  A. A watt is a unit for measuring electric power.
  B. A kilo-watt hour is 1000 watts used during one hour.

III. Electricity must be used safely.
(pp. 196-97)
  A. There are safety rules people must follow for using electricity safely.
  B. There are safety devices that stop the electric current when too much is flowing through it.
    1. A fuse is one safety device. The heat from the current melts a piece of metal which opens the circuit.
    2. A circuit breaker is one safety device. A switch turns off and it opens the circuit.

Appendix D

Reviewers of Technological Activities

REVIEWERS OF TECHNOLOGICAL ACTIVITIES

Dr. William E. Dugger, Jr.
Co-Director of the Mission 21 Project
Technology Education Program
Virginia Polytechnic Institute & State University

Dr. James E. LaPorte
Co-Director of the Mission 21 Project
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Mr. John G. Wells
Graduate Research Associate with the Mission 21 Project
Technology Education Program
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Dr. George E. Glasson
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Curriculum & Instruction - Elementary Science
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Mr. Butch Morris
Graduate Student - Science Education
Curriculum & Instruction
Virginia Polytechnic Institute & State University

Appendix E

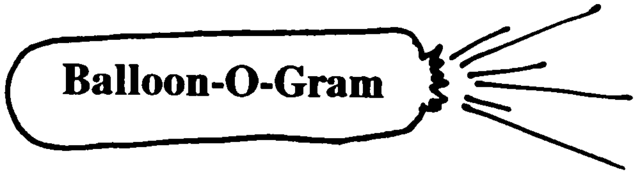
Technological Activities

Teacher Information for Balloon-O-Gram Activity

1. Divide class into teams of 3-4 students each.
2. Give each team an equal amount of space to work.
3. Point out where the messages should originate and where they should be sent. (The distance should be equal for all groups; about 7-8 feet is ideal, it should not exceed 10 feet)
4. Give each group a packet containing the following items:
   - 6 long balloons
   - 6 rubber bands
   - 2 straws
   - 4 metal paper clips
   - Length of fishing line (about 12 feet)
   - 4 index cards
   - 2 spring clips
   - Roll of masking tape
   - 1 pair of scissors
   - 1 pencil
5. Give every student a copy of the design brief. Read it out loud and explain any parts that seem unclear to students.
6. Tell students that they must use only the given materials to make their Balloon-O-Gram. The masking tape, scissors, and pencil can be used to make their device and write their note, but they cannot be used in the actual operation of the device.
7. Tell students that their message must answer the following question (**write this on the board**):

   What energy change is taking place in this device?
   (Probable answer: potential mechanical energy changed to kinetic mechanical energy)
8. Give students the remaining class period to construct and test their device. **Be sure to emphasize that they should record all of their ideas in the notebook as they solve this problem!**
9. Discuss the activity briefly during the next class period by having a member of each group give a short presentation about his/her group's solution. Pose this question to students:

   What factors did you consider with regard to the potential and kinetic energy of your device? (Possible answers: size or number of balloons, amount of friction from fishing line or straw, weight of device).



You are part of a team of inventors. Your boss (your teacher!) gave you a packet of materials. Your team will invent a device called a Balloon-O-Gram using only the materials you were given. Here's what the Balloon-O-Gram should do:

> *The device must carry a note that is written on paper. The note must be transported inside a balloon. When the note gets to its destination, the balloon must burst. Then, the note must fall out. All this must happen without human help. Your Balloon-O-Gram must be self-propelling!*

Follow all the rules given by your boss. Be sure your note has the right information on it. Then it will be a top notch invention!

Don't forget -- TEAMWORK!!

Teacher Information for Gizmo Game Activity

1. Give every student a copy of the design brief. Read it out loud and explain any parts that seem unclear to students.

2. Emphasize that the sample shown in the picture is an example. It is provided to show them how the circuit is set up. They should "be creative" as they layout their game design.

3. Spend a few moments looking at the picture and discussing how the game works. Emphasize how the circuit is not complete until the ring touches the obstacle course. Then, there is a complete circuit. It may be helpful to draw a simple circuit on the chalkboard (see sketch in your folder). Have students draw a line on their drawings to show the complete circuit in the sample Gizmo Game. (As the yellow line drawn on your copy in folder shows.)

4. Tell students that they will each be given the materials to make a Gizmo Game. But, they must design it first by drawing pictures and writing in their "notebook." Emphasize the importance of planning ahead when making things so that unnecessary mistakes are not made.

5. Tell students that their notebooks should not only show how their game will look, but also, they should explain how it works in their own words.

6. Give each student a plastic bag containing all the materials they need to make their own game. Emphasize that they should avoid keeping the bulb lit for extended periods of time because it will wear out the bulb and battery quickly. Call students' attention to the wires coming out of the bulb and battery. Tell them that these wires were "soldered" on to make it easier for them to make connections. They should be careful to not break them off. If they do, they must use electrical tape to securely fix the wire to the bulb or battery. Loose connections are usually the #1 problem!

7. Demonstrate how to use the drill and drilling jig. **Be sure they wear safety glasses when using it.**

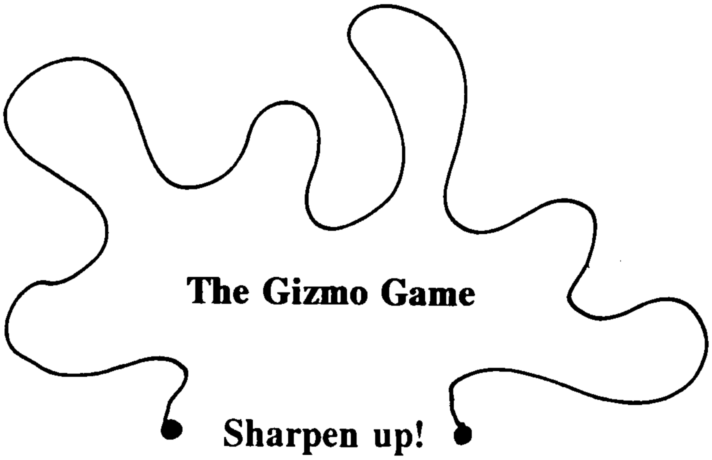
8. Provide other pointers about making the game work:
   - Use clay to hold the bulb in place
   - Make sure all connections are good and tight. Wrap exposed connections with an insulator (electrical tape).
   - Use masking tape to hold the battery in place.
   - Use masking tape to wrap the base of the obstacle course.
   - When storing the game, unhook the ring from the obstacle wire and tape it to the bottom of the board. Then it won't accidently touch a wire and wear out your battery or bulb.

9. Encourage students to keep their notebook nearby as they construct their device. When they run into problems or come up with new ideas, they should record them immediately.

10. When all students finish their games, put them in small groups. Have students swap games and play them for a few minutes.

11. Pull the class together and discuss the activity briefly. Ask questions, like:
    - Why were the wires on the battery and bulb placed where they were?
    - What kind of energy change took place in this game?
    - Why would it be useful to have a switch for this game? How could we easily make one?

12. Choose a few students who did the most creative work to present their games to the class.



The Gizmo Game

Sharpen up!
It's time to play the Gizmo Game!

The Gizmo Game is the hottest game around. That's because you make the game that other people play. Your game will test players' skill and see how steady their hands are!

You will set up a wire obstacle course that is part of an electric circuit. Players will move a metal ring around your obstacle course. If they touch the wire with the ring, then a light should turn on.

The object of the game is to travel the obstacle course without touching the wire. Your teacher will show you how to set up the basic circuit for the game. But, you must find the best way to use the circuit for your game. Make it challenging and fun. Design your game so Gizmo players will want to try it over and over again!

Directions for Making the Gizmo Game

1. Think about many ways to design your game. Sketch your ideas in your notebook.

2. Pick the "BEST" idea for the game you will build.

3. Use a pencil to mark on the board. Show where each part will fit.

4. Use the drill to make a hole for each end of the wire "obstacle course."

5. Tape the battery into place on the board. Use masking tape.

6. Mount your bulb into place using a glob of clay.

7. Bend the "obstacle course" wire in the shape you desire.

8. Make a ring out of one end of the "wand" wire.

9. Connect the circuit like the picture shows.

10. Be sure to wind wires together well so they don't come apart.

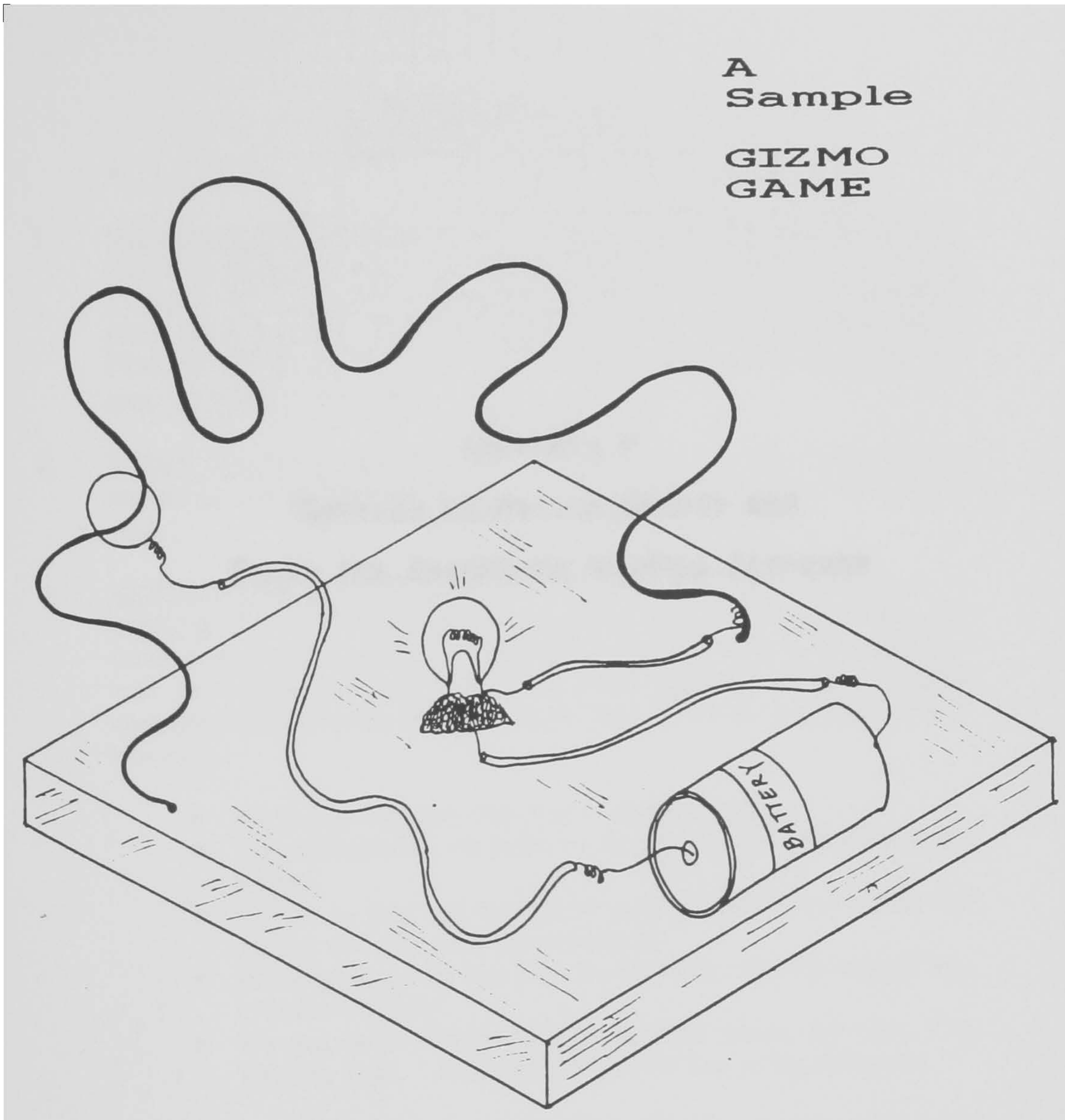
11. Wrap all exposed wires with electrical tape.

12. Wrap masking tape around the base of each "obstacle wire." This will give you a good place to rest your wand when the game is not in use.

13. Now, TEST YOUR GAME! Correct problems, if there are any. Tidy up your connections, if there's time. Make your game look neat!

14. **Keep notes in your notebook about the problems you have.** Also, note new ideas that you come up with. Use the notebook to write down all your ideas about this project -- and how you would do it differently if you had the chance.

15. Share your game with classmates when your teacher tells you to do so.


A
Sample
GIZMO
GAME
BATTERY

Appendix F

General Guideline Sheets and Forms for Recording Student Absences

General Guidelines for Conducting the Study

1. **ORDER TO GIVE TESTS.** For pretests, give the MY POINT OF VIEW (form A) **before** you give the WHAT I KNOW ABOUT CHANGING FORMS OF ENERGY. For posttests, give the MY POINT OF VIEW (form B) **before** you give the WHAT I KNOW ABOUT CHANGING FORMS OF ENERGY. They can be given on the same day, but they must be given in this order.

2. **WHEN TO GIVE TESTS.** Give the pretests 1-2 school days before beginning the unit. Give the posttests 1-2 school days after finishing the unit.

3. **EXPLAINING TO STUDENTS.** Provide plausible explanations of anything that students question regarding things associated with this study (i.e., pretests, posttests, technology activity). They should **never** be told that they are part of a study until **after** the study has been completed by **everyone in your school**. Here are some explanations you can use:

   - I'm trying this new idea that I learned about.
   - This information will help me do a better job of teaching this subject.
   - I want to find out how much you already know about this subject so I can plan the unit better.
   - We're going to try this idea for this unit only. I'll explain how it works out later.
   - We got these things (tests or activity ideas) for free from Virginia Tech. I thought it would be nice to try them out.

4. **DEALING WITH ABSENT STUDENTS.** Handle absenteeism as you normally would by keeping the student after school, meeting before school, or assigning a homework task. However, be sure to follow the guidelines explained in #5 next. It may be necessary for me to exclude the student's test scores because of the absenteeism.

5. **KEEPING ATTENDANCE.** It is critical that you keep good attendance records during the course of this study because some students' test scores will be excluded because they do not meet certain criteria. To help in this matter, I am asking that you use the chart provided for you in the BLUE Record Book. Whenever a student is absent, please note two things:

1. **Date they missed**
2. **What they missed (briefly)**

For example, all of these notations are acceptable:

3/10	*Curiosity pretest*
3/12	*Balloon-O-Gram activity*
3/13	*Textbook reading pp. 190-193*
3/14	*Day 6 lessons*

Name	*M / F*	*Date(s) Absent*	*What Missed?*	*Code*

TEACHER ____________________ Page ____ of ____

Appendix G

Treatment Group Daily Plan

Changing Forms of Energy

DAILY PLAN - TREATMENT GROUP

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
1	A. Hand out a Changing Forms of Energy Notebook to each student. Have each student write his/her name on the cover. Explain that they should keep all their notes in this booklet. B. Students read text pp. 180-183 (till "Forms of Energy") C. Discuss the concepts of work, potential energy, and kinetic energy. Write these new terms on the board. D. Do the MOTIVATE activity described on p. 182 of your Teacher's Guide. (The wind-up toy and playing cards are provided.) E. Do as many of the TEACH tips shown in your teacher's guide (p. 183) as time allows.		
2	A. Students read text pp. 183-184 B. List all the forms of energy on chalkboard. C. Choose students to define and give examples of each type. Encourage new examples that were not mentioned in the reading. (See TEACHING TIPS on p. 184 of your teacher's guide.) Continue this on next day if you do not finish it today.		
3	A. Students read text pp. 185-186. B. Spend time discussing the illustration on pp. 184-185. C. Also, call their attention to the		

1

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
	concept presented on p. 186: *Energy and matter change back and forth into each other, but they never disappear.* D. Have students answer questions on p. 186.		
4	A. Introduce **<u>Balloon-O-Gram</u>** activity. B. Conduct the activity according to the instruction sheet provided.		
5	A. Discuss the **<u>Balloon-O-Gram</u>** activity (#9 on instruction sheet for this activity). B. Students read text pp. 188-190 (till "Changing Other Forms...") C. Follow as many of the MOTIVATE and TEACH ideas as time allows (pp. 188-89 in your teacher's guide).		
6	A. Students read text pp. 190-192. B. To clarify the concept of *circuits*, draw a simple circuit on the chalkboard. Show students how a circuit is like making a complete circle. When the circle is broken, the circuit is opened. (See sketch of simple circuit in your orange folder.) C. Call students' attention to the "how it works" drawings on pp. 190 & 191. Clarify and discuss these as necessary. If possible, draw these on the board while students draw them to help clarify how they work. D. Have students answer questions on p. 192.		

2

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
7	A. Introduce <u>Gizmo Game</u> activity. B. Follow guidelines on the instruction sheet for this activity. C. Have students begin generating ideas for their game by writing in their notebooks. Strongly encourage them to be creative in their game design. Their game does not need to look like the picture or your example.		
8	A. Give each student the materials needed for the activity. B. Let them begin building their games by following their ideas recorded in their notebooks and the directions shown on the handout. C. Carefully watch over the use of the drills. Circulate through the classroom helping students who have problems. Try to encourage them to solve the problems themselves by asking them the "right" questions, like: 1) Do you think your obstacle course will challenge players?, 2) How can you change the shape of your wand to make your game more difficult to play?, 3) Where is the best place to put the bulb and battery so they don't interfere with the play of the game?		
9	A. Finish game building. B. Have students who finish early start reading text pp. 194-197. C. When all students complete, follow guidelines on activity instruction sheet (#10-12).		

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
10	A. Students read text pp. 194-197. B. Have students answer questions on p. 197. C. Discuss the key concepts from this section. D. Use as many of the MOTIVATE and TEACH tips shown in your teacher's guide as time permits.		

4

Appendix H

Materials Provided to Treatment Group Teachers

MATERIALS PROVIDED TO TREATMENT GROUP TEACHERS

1. 1 pair of wire strippers/cutters
2. 2 hand drills (one large metal one, one tiny plastic one) with one envelope of spare drill bits
3. 2 wooden fixtures (used for holding wooden gizmo game pieces while students drill)
4. 4 "C" clamps (to hold fixtures to desk or table)
5. 6 Balloon-O-Gram kits. Each "kit" consists of a brown paper lunch bag filled with:
    - 6 long balloons
    - 2 straws
    - 12' fishing line
    - 2 spring clips
    - 1 pair child's scissors
    - 6 rubber bands
    - 4 metal paper clips
    - 4 index cards
    - Roll of masking tape
    - 1 pencil
6. 25 #2 pencils
7. 2 rolls of electrical tape
8. 2 pairs of children's safety glasses
9. 1 plastic bag filled with extra wire and clay for the Gizmo Game activity
10. A few extra balloons (in case they are needed for the Balloon-O-Gram activity)
11. 28 Idea Notebooks (for students' journals)
12. 25 Balloon-O-Gram Handouts (students' design brief)
13. 25 Gizmo Game Handouts
14. 25 Gizmo Game Directions Handouts
15. 1 plastic bag with Materials for Motivate Activity. (A wind-up toy and a few playing cards)
16. 1 paper bag to store leftover Balloon-O-Gram Supplies
17. 1 Blue Record Book (Holds daily lesson plans and forms for recording students' absences)
18. 1 Orange folder filled with various teachers' handouts (i.e., guidelines on how to conduct the study, unit

plan, instructions on how to conduct activities)

19. 28 **Gizmo Game Packets**. Each "packet" consisted of a plastic food storage bag filled with the following:
    - Pine board (5.5" x 6")
    - D-size battery with one 2" piece of bell wire soldered to + end and another soldered to - end
    - Flashlight lamp (2.33 volt) with one 2" piece of bell wire soldered to base and another soldered to side
    - 17"-18" length of steel wire (about 18-gauge)
    - 15"-18" length of bell wire with insulation stripped on each end
    - Small clay blob

Appendix I

Control Group Daily Plan

Changing Forms of Energy

DAILY PLAN - CONTROL GROUP

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
1	A. Students read text pp. 180-183 (till "Forms of Energy") B. Discuss the concepts of work, potential energy, and kinetic energy. Write these new terms on the board. C. Do the MOTIVATE activity described on p. 182 of your Teacher's Guide. (The wind-up toy and playing cards are provided.) E. Do as many of the TEACH tips shown in your teacher's guide (p. 183) as time allows.		
2	A. Set up the materials needed for the textbook activity called <u>Observing Energy and Work</u> (p. 181). B. Ask a student to come forward to help out. C. Follow the guidelines written in the textbook to conduct the activity. D. After each marble drop, ask the student volunteer to describe approximately how much of the marble is covered by the sand. E. Discuss the findings. F. Repeat the experiment with a new student volunteer and using the metal nuts instead of the marbles. G. Discuss the new findings. H. If time remains, have students start reading text pp. 183-184.		
3	A. Students read text pp. 183-184.		

1

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
	B. List all the forms of energy on chalkboard. C. Choose students to define and give examples of each type. Encourage new examples that were not mentioned in the reading. (See TEACHING TIPS on p. 184 of your teacher's guide.) Continue this on next day if you do not finish it today.		
4	A. Students read text pp. 185-186. B. Spend time discussing the illustration on pp. 184-185. C. Follow the TEACHING TIPS suggested on p. 185 of your teacher's guide. List the steps on the chalkboard instead of posting pictures of them. Discuss the concept as suggested. D. Also, call their attention to the concept presented on p. 186: *Energy and matter change back and forth into each other, but they never disappear.* E. If time permits, have students begin answering questions on p. 186.		
5	A. Have students start and/or finish answering questions on p. 186 of the text. Orally review the answers when all students are completed. B. Do the FIND OUT ON YOUR OWN activity (p. 186 of text) as an in class activity. Give students about 10-15 minutes to make their lists. Then synthesize all the ideas by having them contribute to a class list that you write on the board.		
6	A. Students read text pp. 188-190 (till "Changing Other Forms...") B. Follow guidelines for the MOTIVATE activity described in		2

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
	demonstrate this concept. C. Follow the teaching tips suggested on page 189 of your teacher's guide.		
7	A. Students read the activity described on p. 193 of their text. B. Do this activity (Investigating Electric Charge) as a teacher demonstration activity. C. Choose two students to come forward to help out. Have one student be a close observer of the experiment so he or she can verbally explain what happened to the rest of the class, in case they cannot see it well. The other student should record the results of the experiment on the chalkboard. D. Follow the guidelines written in the textbook to conduct the activity. Be sure to conduct the demo in a place that is visible to all students. (Try putting a chair on top of a desk in front of room). E. Discuss the findings. F. Repeat the experiment using the vinyl strip instead of the ruler and the wool cloth instead of the waxed paper. G. Discuss the new findings.		
8	A. Students read text pp. 190-192 B. To clarify the concept of *circuits*, draw a simple circuit on the chalkboard. Show students how a circuit is like making a complete circle. When the circle is broken, the circuit is opened. (See sketch of simple circuit in your orange folder.) C. Call students' attention to the "how it works" drawings on pp. 190 & 191. Clarify and discuss these as necessary. If possible,		

3

DAY #	SUGGESTED PLAN FOR THE DAY	WHAT WAS ACTUALLY ACCOMPLISHED	# MINUTES SPENT
	clarify how they work. D. Follow the TEACHING TIPS suggested on pp. 190-91 of your teacher's guide. E. Students answer questions on p. 192 of their text.		
9	A. Orally review answers to questions on p. 192 of text. B. Students read text pp. 194-196 (till "Using Electricity Safely") C. Do the MOTIVATE activity described in your teacher's guide (p. 194) by making a list on the chalkboard. Include several devices, like washing machine, computer, electric coffee pot, electric toothbrush, and electric hand dryer (as found in public restrooms). Conduct discussion as suggested on p. 194 of teacher's guide. D. Follow TEACHING TIPS suggested on p. 195 of teacher's guide. E. Be sure students understand the concept of measuring electric power. F. If time permits, pose these questions to students and ask them to figure the answers: If electricity costs 6 cents per kilowatt- hour, how much will it cost if you use 550 kilowatt-hours? (ANSWER: $33.00) What if it cost 9 cents per kilowatt-hour?		
10	A. Students read text pp. 196-197 B. Follow the first two TEACHING TIPS suggested in your teacher's guide on page 196. C. Have students answer questions on p. 197. D. Orally review answers to questions when all students have completed the assignment.		

4

Appendix J

Materials Provided to Control Group Teachers

MATERIALS PROVIDED TO CONTROL GROUP TEACHERS

1. 25 #2 pencils
2. 1 roll of masking tape
3. 1 plastic bag with Materials for Motivate Activity. (A wind-up toy and a few playing cards)
4. Materials for Teacher Demonstration of book experiment, "Observing Energy and Work," including:
   - Plastic container filled with sand
   - Yardstick
   - Several marbles
   - Several heavy bolts
5. Materials for Motivate Activity called, "Dancing Dolls," including:
   - Foil pie tin
   - Tissue paper dolls
   - Clear plastic wrap
   - Piece of wool cloth
6. Materials for Teacher Demonstration of book experiment, "Investigating Electric Charge," including:
   - Plastic ruler
   - Piece of aluminum foil
   - Length of fishing line
   - Piece of waxed paper
   - Piece of vinyl
   - Piece of wool cloth
7. 1 Blue Record Book (Holds daily lesson plans and forms for recording students' absences)
8. 1 Orange folder filled with various teachers' handouts (i.e., guidelines on how to conduct the study, unit plan)

Appendix K

<u>Agenda for Treatment Group Workshop</u>

TREATMENT GROUP WORKSHOP

March 25, 1991 -- 3:30 p.m.
Shelburne Junior High School
Technology Education Classroom

I. Introduction
- Discuss agenda
- Offer refreshments

II. Orientation to Treatment Materials
- Explain what all items in boxes are for
- Indicate what items will need to be returned
- Go through items in Record Book and Folder

III. Technological Activity #1: Balloon-O-Gram
- Do activity in small groups
- Discuss considerations when doing activity with students

IV. Technological Activity #2: Gizmo Game
- Demonstrate unfamiliar equipment (i.e., drill, wire cutters/strippers)
- Do activity individually
- Discuss considerations when doing activity with students

V. Pretesting and Posttesting
- Discuss nature of tests
- Explain importance of following guidelines provided for administering them

VI. Open Floor for Questions and Answers

Appendix L

Parallel Comparison of SECS (Form A) with Revised Version of MyPOV (Form A)

Comparison of Statements on the SECS (Form A) with Statements on the MyPOV Instrument (Form A)

No.	Statement on SECS	Statement on MyPOV
1	The materials will be very interesting to me.	This subject will be very interesting to me.
2	I will enjoy learning the material which is unfamiliar to me.	I will like learning things that I did not know before.
3	I feel that the material will be boring.	This subject will be boring to me.
4	I will enjoy reading more about the new materials.	I will like reading more about this subject.
5	When the material is difficult, I will not enjoy learning it.	When things are hard to understand, I will NOT like learning about them.
6	I think it will be fun to increase my understanding about the subject matter.	I think it will be fun to find out more about this subject.
7	I will like to see some of the points in the material expanded.	I will like learning more about some parts of this subject than I knew before.
8	I will enjoy learning new words and their meanings.	I will like learning new words and their meanings.
9	Sometimes I will find it hard to concentrate on the material.	Sometimes it will be hard to keep my mind on this subject.
10	It will be fascinating to me to learn new information.	It will be fascinating to learn new things about this subject.
11	I will find myself losing interest when complex	I will lose interest when things are hard to

	material is presented.	understand.
12	When I read a sentence that puzzles me, I will keep reading it until I understand it.	I will keep trying to understand things even when I am puzzled.
13	I will enjoy learning the material that surprises me and makes me change my old ideas about the subject.	I will like learning things that surprise me <u>and</u> change how I think about this subject.
14	It will be more enjoyable to me to read about familiar than unfamiliar material.	I will be more enjoyable to read about familiar than unfamiliar things.
15	I will have trouble paying attention on the difficult material.	I will have a problem paying attention when this subject gets hard.
16	The material will stimulate me to think of new ideas.	Learning about this subject will make me think of new ideas.
17	I will find that I would rather spend time answering difficult questions than spend it with easy ones.	I will like answering hard questions more than easy ones.
18	When I come across something I don't understand, I will try to figure it out.	When I come across something I don't understand, I will try to figure it out.
19	It will be exciting to me to learn about this subject.	It will be exciting to learn about this subject.
20	I will find myself getting bored when the material is redundant.	I will get bored studying the same subject so much.

Appendix M

Parallel Comparison of SECS (Form B) with Revised Version of MyPOV (Form B)

<u>Comparison of Statements on the SECS (Form B) with Statements on the MyPOV Instrument (Form B)</u>

No.	Statement on SECS	Statement on MyPOV
1	The material I learned was very interesting to me.	This subject was very interesting to me.
2	I enjoyed learning the material which was unfamiliar to me.	I liked learning things that I did not know before.
3	I felt that the material was boring.	This subject was boring to me.
4	I would enjoy reading more about this subject matter.	I would like to read more about this subject.
5	When the material was difficult, I did not enjoy learning it.	When things were hard to understand, I <u>DID</u> <u>NOT</u> like learning about them.
6	I thought it was fun to increase my understanding about this subject matter.	It was fun to find out more about this subject.
7	I would like to see some of the points in the material expanded.	I want to learn more about some of the things we studied.
8	I enjoyed learning new words and their meanings.	I liked learning new words and their meanings.
9	Sometimes I found it hard to concentrate on this material.	Sometimes it was hard to keep my mind on this subject.
10	It was fascinating to me to learn new information.	It was fascinating to learn new things about this subject.
11	I found myself losing interest when complex material was presented.	I lost interest when things were hard to understand.

12	When I read a sentence that puzzled me, I kept reading it until I understood it.	I kept trying to understand things even when I was puzzled.
13	I enjoyed learning the material that surprised me and made me change my old ideas about this subject.	I liked learning things that surprised me <u>and</u> changed how I thought about this subject.
14	It was more enjoyable to me to read about familiar than unfamiliar material.	It was more enjoyable to read about familiar than unfamiliar things.
15	I had trouble paying attention on the difficult material.	I had a problem paying attention when things were hard.
16	The material stimulated me to think of new ideas.	Learning about this subject made me think of new ideas.
17	I found I would rather spend time answering difficult questions than spend it with easy ones.	I found that I liked answering hard questions more than easy ones.
18	When I came across something I didn't understand, I tried to figure it out.	When I came across something I didn't understand, I tried to figure it out.
19	It was exciting to me to learn about this subject.	It was exciting to learn about this subject.
20	I found myself getting bored when the material was redundant.	I got bored studying the same subject so much.

Appendix N

Reviewers of Instrumentation

REVIEWERS OF INSTRUMENTATION

Reviewer 1

Mr. John G. Wells
Graduate Research Associate with the Mission 21 Project
Technology Education Program
Virginia Polytechnic Institute & State University

Reviewer 2

Dr. George E. Glasson
Assistant Professor
Curriculum & Instruction - Elementary Science
Virginia Polytechnic Institute & State University

Reviewer 3

Mr. Butch Morris
Graduate Student - Science Education
Curriculum & Instruction
Virginia Polytechnic Institute & State University

Reviewer 4

Ms. Ellen Harkrader
Fifth Grade Science Teacher
Eastern Elementary School
Pembroke, Virginia

Reviewer 5

Dr. Robert Frary
Director, Test Scoring & Analysis Services
Virginia Polytechnic Institute & State University

Appendix O

Evaluation Form Used by Reviewers of MyPOV

REVIEWER'S EVALUATION FORM

Curiosity Pretest and Posttest

Directions

This form will be used to record your comments about both the curiosity pretest and posttest. Carefully read the statements as they appeared on the original instruments. Then read how I've edited the statements to suit my study. Next, read my comments on this form about why the changes were made. If you think the changes are acceptable, put an X in the PINK OK column (for pretest statements shown on pink forms) and BLUE OK column (for posttest statements shown on blue forms). If a statement is not acceptable, make the changes you desire directly on the pink or blue sheets; do not check the OK column if you make any changes. Feel free to comment about any statements by writing in the comment section on this sheet or anywhere on the pink or blue sheets.

#	MY COMMENT	REVIEWER COMMENT	PINK OK	BLUE OK
1	This study is dealing with a subject rather than specific learning materials.			
2	The idea of "material" may be too vague for 5th graders; I thought "things" would be more understandable.			
3	"Material" is vague; "subject" is clearer and more pertinent to this study.			
4	"Material" is vague; "subject" is clearer and more pertinent to this study.			

#	MY COMMENT	REVIEWER COMMENT	PINK OK	BLUE OK
5	The idea of "material" may be too vague for 5th graders; I thought "things" would be more understandable.			
6	The edited statement is more concise and has lower reading level.			
7	The edited statement has lower reading level.			
8	The edited statement has slightly lower reading level.			
9	The edited statement has lower reading level.			
10	The edited statement is more concise; excess verbage removed.			
11	The edited statement has lower reading level.			

#	MY COMMENT	REVIEWER COMMENT	PINK OK	BLUE OK
12	The reference to reading sentences was removed because original instrument was used with written learning materials. This study is <u>not</u> using all-written materials; some students will be using very few. I think the edited statement maintains the original meaning without making specific reference to written materials.			
13	"Material" is vague; "subject" is clearer and more pertinent to this study.			
14	Although it's longer, I think it will be easier for a 5th grader to understand the edited version. However, this one is questionable and your suggestions would be greatly appreciated.			
15	"Material" is vague; "subject" is clearer and more pertinent to this study.			
16	"Material" is vague; "subject" is clearer and more pertinent to this study.			
17	The edited statement has lower reading level.			

#	MY COMMENT	REVIEWER COMMENT	PINK OK	BLUE OK
18	No changes made			
19	The edited statement is more concise: excess verbage removed.			
20	"Material" is vague; "subject" is clearer and more pertinent to this study. Also, the edited statement has lower reading level.			

THANK YOU FOR REVIEWING THESE INSTRUMENTS.

Please return these items to me in the postage-paid, addressed envelope provided:

- **This form**
- **Pink sheets**
- **Blue sheets**

CURIOSITY INSTRUMENT (PRETEST)

Comparison of Original Instrument with Edited Instrument (Form A)

#	STATEMENT ON ORIGINAL INSTRUMENT	STATEMENT ON EDITED INSTRUMENT
1	The materials will be very interesting to me.	This subject will be very interesting to me.
2	I will enjoy learning the material which is unfamiliar to me.	I will like learning things that I did not know before.
3	I feel that the material will be boring.	This subject will be boring to me.
4	I will enjoy reading more about the new materials.	I will like reading more about this subject.
5	When the material is difficult, I will not enjoy learning it.	When things are hard to understand, I will NOT like learning about them.
6	I think it will be fun to increase my understanding about the subject matter.	I think it will be fun to find out more about this subject.
7	I will like to see some of the points in the material expanded.	I will like learning more about this subject than I knew before.
8	I will enjoy learning new words and their meanings.	I will like learning new words and their meanings.

9	Sometimes I will find it hard to concentrate on the material.	Sometimes it will be hard to keep my mind on this subject.
10	It will be fascinating to me to learn new information.	It will be fascinating to learn new things about this subject.
11	I will find myself losing interest when complex material is presented.	I will lose interest when things are hard to understand.
12	When I read a sentence that puzzles me, I will keep reading it until I understand it.	I will keep trying to understand things even when I am puzzled.
13	I will enjoy learning the material that surprises me and makes me change my old ideas about the subject.	I will like learning things that surprise me and change how I think about this subject.
14	It will be more enjoyable to me to read about familiar than unfamiliar material.	I will like learning about things that I knew something about MORE than things that I don't know about.
15	I will have trouble paying attention on the difficult material.	I will have a problem paying attention when this subject gets hard.
16	The material will stimulate me to think of new ideas.	Learning about this subject will make me think of new ideas.

17	I will find that I would rather spend time answering difficult questions than spend it with easy ones.	I will like answering hard questions more than easy ones.
18	When I come across something I don't understand, I will try to figure it out.	When I come across something I don't understand, I will try to figure it out.
19	It will be exciting to me to learn about this subject.	It will be exciting to learn about this subject.
20	I will find myself getting bored when the material is redundant.	I will get bored studying the same subject so much.

CURIOSITY INSTRUMENT (POSTTEST)

Comparison of Original Instrument with Edited Instrument (Form B)

#	STATEMENT ON ORIGINAL INSTRUMENT	STATEMENT ON EDITED INSTRUMENT
1	The material I learned was very interesting to me.	This subject was very interesting to me.
2	I enjoyed learning the material which was unfamiliar to me.	I liked learning things that I did not know before.
3	I felt that the material was boring.	This subject was boring to me.
4	I would enjoy reading more about this subject matter.	I would like to read more about this subject.
5	When the material was difficult, I did not enjoy learning it.	When things were hard to understand, I did NOT like learning about them.
6	I thought it was fun to increase my understanding about this subject matter.	It was fun to find out more about this subject.
7	I would like to see some of the points in the material expanded.	I want to learn more about this subject.
8	I enjoyed learning new words and their meanings.	I liked to learn new words and their meanings.

9	Sometimes I found it hard to concentrate on this material.	Sometimes it was hard to keep my mind on this subject.
10	It was fascinating to me to learn new information.	It was fascinating to learn new things about this subject.
11	I found myself losing interest when complex material was presented.	I lost interest when things were hard to understand.
12	When I read a sentence that puzzled me, I kept reading it until I understood it.	I kept trying to understand things even when I was puzzled.
13	I enjoyed learning the material that surprised me and made me change my old ideas about this subject.	I liked learning things that surprised me and changed how I thought about this subject.
14	It was more enjoyable to me to read about familiar than unfamiliar material.	I liked learning about things that I knew something about MORE than things that I didn't know about.
15	I had trouble paying attention on the difficult material.	I had a problem paying attention when things were hard.
16	The material stimulated me to think of new ideas.	Learning about this subject made me think of new ideas.

17	I found I would rather spend time answering difficult questions than spend it with easy ones.	I found that I liked answering hard questions more than easy ones.
18	When I came across something I didn't understand, I tried to figure it out.	When I came across something I didn't understand, I tried to figure it out.
19	It was exciting to me to learn about this subject.	It was exciting to learn about this subject.
20	I found myself getting bored when the material is redundant.	I got bored studying the same subject so much.

Appendix P

Summary of Reviewers' Suggestions on MyPOV

SUMMARY OF REVIEWERS' SUGGESTIONS ON MYPOV

The feedback from each of the five reviewers of the MyPOV instruments was relatively consistent. Individual comments are listed below. Please refer to the form used by reviewers in order to interpret these comments (appendix O). Comments pertain to both versions (pretest & posttest) even though only one version may be listed below.

Item 7

1. Reword as: "I want to learn more about some parts of this subject."

Item 8

1. Reword as: "I liked learning new words and their meanings."

Item 11

1. What about "get bored" instead of "lose interest?"

Item 12

1. I think reading the science is important -- and this changes original item qualitatively.

Item 13

1. Reword as: "I liked learning things that surprised me and has made me think about things in a different way."

Item 14

1. Use original statement wording instead of revision.
2. I like the original.

Item 20

1. Concept of "redundant" not carried through in MyPOV version

Appendix Q

State Epistemic Curiosity Scale (SECS), Forms A & B

As Developed by Barbara L. Leherissey (1971b)

State Epistemic Curiosity Scale - Form A

Name______________________________ Date____________________________

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken the appropriate space on the IBM answer sheet to indicate how you think you would feel while learning new materials.

There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe best how you think you would feel.

	Not at all	Somewhat	Moderately so	Very much so
1. The materials will be very interesting to me.	1	2	3	4
2. I will enjoy learning the material which is unfamiliar to me.	1	2	3	4
3. I feel that the material will be boring.	1	2	3	4
4. I will enjoy reading more about the new materials.	1	2	3	4
5. When the material is difficult, I will not enjoy learning it.	1	2	3	4
6. I think it will be fun to increase my understanding about the subject matter.	1	2	3	4
7. I will like to see some of the points in the material expanded.	1	2	3	4
8. I will enjoy learning new words and their meanings.	1	2	3	4

	Not at all	Somewhat	Moderately so	Very much so
9. Sometimes I will find it hard to concentrate on the material.	1	2	3	4
10. It will be fascinating to me to learn new information.	1	2	3	4
11. I will find myself losing interest when complex material is presented.	1	2	3	4
12. When I read a sentence that puzzles me, I will keep reading it until I understand it.	1	2	3	4
13. I will enjoy learning the material that surprises me and makes me change my old ideas about the subject.	1	2	3	4
14. It will be more enjoyable to me to read about familiar than unfamiliar material.	1	2	3	4
15. I will have trouble paying attention on the difficult material.	1	2	3	4
16. The material will stimulate me to think of new ideas.	1	2	3	4
17. I will find that I would rather spend time answering difficult questions than spend it with easy ones.	1	2	3	4
18. When I come across something I don't understand, I will try to figure it out.	1	2	3	4
19. It will be exciting to me to learn about the subject.	1	2	3	4
20. I will find myself getting bored when the material is redundant.	1	2	3	4

State Epistemic Curiosity Scale - Form B

Name______________________ Date______________

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken the appropriate space on the IBM answer sheet to indicate how you felt while learning the materials.

There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe best how you felt.

	Not at all	Somewhat	Moderately so	Very much so
1. The material I learned was very interesting to me.	1	2	3	4
2. I enjoyed learning the material which was unfamiliar to me.	1	2	3	4
3. I felt that the material was boring.	1	2	3	4
4. I would enjoy reading more about this subject matter.	1	2	3	4
5. When the material was difficult, I did not enjoy learning it.	1	2	3	4
6. I thought it was fun to increase my understanding about this subject matter.	1	2	3	4
7. I would like to see some of the points in the material expanded.	1	2	3	4
8. I enjoyed learning new words and their meanings.	1	2	3	4
9. Sometimes I found it hard to concentrate on this material.	1	2	3	4

	Not at all	Somewhat	Moderately so	Very much so
10. It was fascinating to me to learn new information.	1	2	3	4
11. I found myself losing interest when complex material was presented.	1	2	3	4
12. When I read a sentence that puzzled me, I kept reading it until I understood it.	1	2	3	4
13. I enjoyed learning the material that surprised me and made me change my old ideas about this subject.	1	2	3	4
14. It was more enjoyable to me to read about familiar than unfamiliar material.	1	2	3	4
15. I had trouble paying attention on the difficult material.	1	2	3	4
16. The material stimulated me to think of new ideas.	1	2	3	4
17. I found I would rather spend time answering difficult questions than spend it with easy ones.	1	2	3	4
18. When I came across something I didn't understand, I tried to figure it out.	1	2	3	4
19. It was exciting to me to learn about this subject.	1	2	3	4
20. I found myself getting bored when the material was redundant.	1	2	3	4

Appendix R

<u>My Point of View (MyPOV), Form A, with Teacher Instructions For Administering It</u>

Teacher Directions for Administering the

My Point of View - Form A (Curiosity Pretest)

NOTE: PARAGRAPHS AND STATEMENTS IN BOLD SHOULD BE READ DIRECTLY AS WRITTEN HERE.

1. Tell students:

   Clear your desks and take out a #2 pencil.

   (Give students a #2 pencil if they do not have one.)

2. Tell students:

   I want you to fill out a questionnaire so I can find out how you feel about studying a science unit on changing forms of energy. Your answers will not affect your grade in this class. It will only take a few minutes.

3. Tell students:

   Do not make any marks on these sheets until I tell you do so.

   Give each student the BLUE sheet and a copy of the printed computer form.

4. Read through the BLUE sheet out loud.

   Tell students:

   Do you have any questions?

   (Respond to any questions. Do not tell them that they are part of an experiment or study.)

5. Tell students to:

   - **Color in the circle for the answer you choose.**
     AGREE = 1 DOES NOT AGREE = 2
   - **Do not make any marks in the circles numbered 3 to 10.**
   - **Erase mistakes well.**
   - **Color in the circles completely.** (Point out the good and bad examples that are printed on the answer form.)
   - **Color in one circle only for each statement.**

6. Tell students:

Print your first and last name on the answer form in the block marked NAME.

7. Tell students:

   It's important that you read each statement carefully. If you agree with the statement, then fill-in the 1. If you do not agree, fill-in the 2. Remember that the subject you are being asked about is CHANGING FORMS OF ENERGY. This is the subject we will be studying next in science.

   If you have any questions while you are filling in this questionnaire, just raise your hand. I will come to your desk and help you. When you finish, look through your answers to make sure you only marked one answer for each statement. Then turn your paper over to show me that you are finished. I will collect it. Do you have any questions?

   (Respond to any questions; then, signal to begin filling out the questionnaire.)

8. As students fill out the form, please walk through the classroom and be sure they are completing it correctly. You can help students if they do not understand a statement or word. But, do not tell them what answer to put down. When students finish, collect their forms. Also collect pencils from those students who did not have one.

9. Put all forms and BLUE sheets in the envelope that they came in. (Please count them -- be sure you have exactly 25 forms and blue sheets.)

10. Don't forget to note which students missed this test by recording that information on the chart in your BLUE record book.

11. Proceed with your normal plan of study.

<u>My Point of View</u>

The purpose of this quiz is to find out what you think about a certain science subject. The subject is called **<u>Changing Forms of Energy</u>**. In this subject, you will learn about three main things:

1● How energy changes forms

2● How electric energy or electricity is produced

3● How electric energy is changed and used

This is not a test. There are no right or wrong answers. Your answers will not change your grade in this class. But, it is important that you tell the truth about how you feel.

You will be shown 20 statements. You must decide if you AGREE with the statement or whether you DO NOT AGREE with the statement. If you think that the statement is TRUE for you, then you AGREE. If you think that the statement is NOT TRUE for you, then you DO NOT AGREE.

When you AGREE, you color in the circle marked 1. When you DISAGREE, you color in the circle marked 2. For example:

<u>Sample Statement</u>:

I am a fifth grade student. ● ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

This statement is TRUE for you; so you AGREE. You color in the circle marked 1.

<u>Use only a #2 pencil on this answer sheet.</u>

<u>Make marks only where you are told.</u>

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VIRGINIA TECH

INCORRECT MARKS | CORRECT MARKS | USE NO. 2 PENCIL

NAME	COURSE	DATE

ID NUMBER | FORM | SEAT NO | GROUP

My Point of View

Form A

Read each statement. Mark the answer that fits how <u>you</u> feel. *There are no wrong answers!*

If you <u>AGREE</u>, mark <u>1</u>

If you <u>DO NOT AGREE</u>, mark <u>2</u>

1. This subject will be very interesting to me.
2. I will like learning things that I did not know before.
3. This subject will be boring to me.
4. I will like reading more about this subject.
5. When things are hard to understand, I will <u>NOT</u> like learning about them.
6. I think it will be fun to find out more about this subject.
7. I will like learning more about some parts of this subject than I knew before.
8. I will like learning new words and their meanings.
9. Sometimes it will be hard to keep my mind on this subject.
10. It will be fascinating to learn new things about this subject.
11. I will lose interest when things are hard to understand.
12. I will keep trying to understand things even when I am puzzled.
13. I will like learning things that surprise me <u>and</u> change how I think about this subject.
14. It will be more enjoyable to read about familiar than unfamiliar things.
15. I will have a problem paying attention when this subject gets hard.
16. Learning about this subject will make me think of new ideas.
17. I will like answering hard questions more than easy ones.
18. When I come across something I don't understand, I will try to figure it out.
19. It will be exciting to learn about this subject.
20. I will get bored studying the same subject so much.

<u>Thanks for sharing *your point of view*. Please turn your paper over and wait till your teacher tells you what to do next.</u>

Appendix S

My Point of View (MyPOV), Form B, with Teacher Instructions For Administering It

Teacher Directions for Administering the

My Point of View - Form B (CURIOSITY POSTTEST)

NOTE: PARAGRAPHS AND STATEMENTS IN BOLD SHOULD BE READ DIRECTLY AS WRITTEN HERE.

1. Tell students:

   Clear your desks and take out a #2 pencil.

   (Give students a #2 pencil if they do not have one.)

2. Tell students:

   I want you to fill out another questionnaire so I can find out how you felt about studying a science unit on changing forms of energy. Your answers will not affect your grade in this class. It will only take a few minutes.

3. Tell students:

   Do not make any marks on these sheets until I tell you do so.

   Give each student the GOLDENROD sheet and a copy of the printed computer form.

4. Read through the GOLDENROD sheet out loud.

   Tell students:

   Do you have any questions?

   (Respond to any questions. Do not tell them that they are part of an experiment or study.)

5. Tell students to:

   - **Color in the circle for the answer you choose.**
     AGREE = 1 DOES NOT AGREE = 2
   - **Do not make any marks in the circles numbered 3 to 10.**
   - **Erase mistakes well.**
   - **Color in the circles completely.** (Point out the good and bad examples that are printed on the answer form.)
   - **Color in one circle only for each statement.**

6. Tell students:

   Print your first and last name on the answer form in the block marked NAME.

7. Tell students:

   It's important that you read each statement carefully. If you agree with the statement, then fill-in the 1. If you do not agree, fill-in the 2. Remember that the subject you are being asked about is CHANGING FORMS OF ENERGY. This is the subject that we just studied in science.

   If you have any questions while you are filling in this questionnaire, just raise your hand. I will come to your desk and help you. When you finish, look through your answers to make sure you only marked one answer for each statement. Then turn your paper over to show me that you are finished. I will collect it. Do you have any questions?

   (Respond to any questions; then, signal to begin filling out the questionnaire.)

8. As students fill-out the form, please walk through the classroom and be sure they are completing it correctly. You can help students if they do not understand a statement or word. But, do not tell them what answer to put down. When students finish, collect their forms. Also collect pencils from those students who did not have one.

9. Put all forms and GOLDENROD sheets in the envelope that they came in. (Please count them -- be sure you have exactly 25 forms and GOLDENROD sheets.)

10. Don't forget to note which students missed this test by recording that information on the chart in your BLUE record book.

11. Proceed with your normal plan of study.

My Point of View

The purpose of this quiz is to find out what you thought about the science subject you studied. The subject was called **Changing Forms of Energy**. In this subject, you learned about three main things:

1● How energy changes forms

2● How electric energy or electricity is produced

3● How electric energy is changed and used

This is not a test. There are no right or wrong answers. Your answers will not change your grade in this class. But, it is important that you tell the truth about how you feel.

You will be shown 20 statements. You must decide if you AGREE with the statement or whether you DO NOT AGREE with the statement. If you think that the statement is TRUE for you, then you AGREE. If you think that the statement is NOT TRUE for you, then you DO NOT AGREE.

When you AGREE, you color in the circle marked 1. When you DISAGREE, you color in the circle marked 2. For example:

Sample Statement:

I am a fifth grade student. ● ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

This statement is TRUE for you; so you AGREE. You color in the circle marked 1.

Use only a #2 pencil on this answer sheet.

Make marks only where you are told.

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VIRGINIA TECH

INCORRECT MARKS	CORRECT MARKS	USE NO. 2 PENCIL

NAME	COURSE	DATE

ID NUMBER | FORM | SEAT NO | GROUP

My Point of View

Form B

Read each statement. Mark the answer that fits how you feel. *There are no wrong answers!*

If you AGREE, mark 1

If DO NOT AGREE, mark 2

1. This subject was very interesting to me.
2. I liked learning things that I did not know before.
3. This subject was boring to me.
4. I would like to read more about this subject.
5. When things were hard to understand, I did NOT like learning about them.
6. It was fun to find out more about this subject.
7. I want to learn more about some of the things we studied.
8. I liked learning new words and their meanings.
9. Sometimes it was hard to keep my mind on this subject.
10. It was fascinating to learn new things about this subject.
11. I lost interest when things were hard to understand.
12. I kept trying to understand things even when I was puzzled.
13. I liked learning things that surprised me **and** changed how I thought about this subject.
14. It was more enjoyable to read about familiar than unfamiliar things.
15. I had a problem paying attention when things were hard.
16. Learning about this subject made me think of new ideas.
17. I found that I liked answering hard questions more than easy ones.
18. When I came across something I didn't understand, I tried to figure it out.
19. It was exciting to learn about this subject.
20. I got bored studying the same subject so much.

Thanks for sharing *your point of view*. Please turn your paper over and wait till your teacher tells you what to do next.

Appendix T

Draft Copy of the WIKACFE Test

As Seen By Test Reviewers

What I Know About Changing Forms of Energy

Your answers on this test will NOT affect your grades in this class.

DIRECTIONS:

1. All your answers must be filled in on the answer sheet provided.
2. You must use a #2 pencil. Your teacher will give you one if you don't have one.
3. Do not make any marks on the answer sheet except where you are told.
4. Mark only one answer for each question. Choose the BEST answer.
5. If are not sure of the answer, make a guess.

Do not turn the page until your teacher tells you to do so.

DON'T FORGET...MARK ALL YOUR ANSWERS ON THE ANSWER FORM.

1. Work takes place only when
    1. effort is used.
    2. energy moves an object.
    3. force is applied.
    4. matter changes forms.

2. The energy of the movement of the particles that form an object is called
    1. chemical energy.
    2. nuclear energy.
    3. radiant energy.
    4. thermal energy.

3. What kind of energy do power lines like the ones shown in this picture carry?
    1. nuclear energy
    2. electrical energy
    3. mechanical energy
    4. thermal energy

Insert Illustration A here.

4. Hammering a nail and riding a bike are examples of
    1. chemical energy.
    2. radiant energy.
    3. mechanical energy.
    4. thermal energy.

5. What kind of energy is released when atoms are split or joined?
    1. chemical energy
    2. nuclear energy
    3. radiant energy
    4. thermal energy

6. Which one of these is an example of kinetic energy?
    1. wind blowing leaves from the trees
    2. sunlight shining on a flower
    3. a roof covered with snow

7. Look at this picture. The man is getting ready to shoot an arrow from his bow. He has pulled back the arrow as far as he can. What kind of energy does the arrow have now?

Insert Illustration B here

1. kinetic energy
2. potential energy
3. no energy

8. Which picture shows one kind of kinetic energy changing to another kind of kinetic energy?

1. Insert C here
2. Insert D here
3. Insert E here

9. Look at this picture. The child is sitting on the swing. How could you increase the potential mechanical energy of the swing?

Insert F here

1. tell the child to get off the swing
2. put a larger child on the swing instead
3. pull the swing back and hold it there
4. push the swing as hard as you can

10. Which one of these things changes radiant energy to chemical energy?
    1. a flower
    2. a lump of coal
    3. a battery
    4. a light bulb

11. Which one of these things releases chemical energy?
    1. an electric stove
    2. water falling over a cliff
    3. burning oil or gas
    4. wind blowing the sails on a boat

12. People eat food to get the energy they need to run. What energy change is taking place?
    1. thermal energy (food) changes to chemical energy (running)
    2. mechanical energy (food) changes to thermal energy (running)
    3. chemical energy (food) changes to mechanical energy (running)

13. This is a picture of an ordinary light bulb. When this bulb is used in a lamp, where does electric energy change to radiant energy?

    Insert G here

    1. at the screw base
    2. in the filament
    3. in the empty space inside the glass bulb
    4. in a special paint that coats the glass bulb

14. Mechanical energy is changed to electric energy at a power plant. Which of these things has mechanical energy that the power plant uses to make electricity?
    1. steam
    2. heat
    3. smoke
    4. fire

15. Which one of these things changes electric energy to thermal energy and then into radiant energy?
    1. electric motor
    2. toaster
    3. bicycle generator
    4. candle

16. Which one of these things changes chemical energy to electric energy?
   1. battery
   2. light bulb
   3. food mixer
   4. hair dryer

17. Which one of these statements is FALSE?
   1. Energy can change to matter.
   2. Matter can change to energy.
   3. Matter and energy are the same thing.
   4. Matter and energy can disappear.

18. What part of an atom has no electric charge?
   1. proton
   2. neutron
   3. electron
   4. They all have an electric charge.

19. What part of an atom can move freely?
   1. proton
   2. neutron
   3. electron
   4. None of them can move freely.

20. An atom is POSITIVELY charged when it has more
   1. neutrons than electrons.
   2. protons than neutrons.
   3. electrons than protons.
   4. electrons than neutrons.
   5. protons than electrons.

21. An atom has 2 protons, 2 neutrons, and 3 electrons. What charge does this atom have?
   1. negative charge
   2. positive charge
   3. no charge

.5

22. If two atoms are NEGATIVELY charged, what will happen?
    1. They will push away from each other.
    2. They will pull together.
    3. They will push and pull causing a spark.

23. Electricity is caused by the movement of
    1. protons.
    2. neutrons.
    3. electrons.

24. Things that allow electric current to **easily flow** through them are called
    1. insulators.
    2. conductors.
    3. generators.

25. Rubber, glass, and plastic are
    1. insulators.
    2. conductors.
    3. generators.

26. You just built a circuit. You only had bare metal wire to work with. What can you do to the bare wires to keep <u>less</u> electric current from coming through the sides of the wires?
    1. wrap the wires with aluminum foil
    2. wind more metal wire around the bare wire
    3. cover the bare wire with plastic tape
    4. wipe the wires with a damp sponge

27. Which one of these devices changes mechanical energy to electricity using a magnet?
    1. dry cell battery
    2. wet cell battery
    3. generator

28. Electric current flows through a path called
    1. an open circuit.
    2. a closed circuit.
    3. a short circuit.

29-30. Read about this experiment. Look at the picture and chart to answer questions #29-#30.

Experiment

Insert H here

Tim and Pam wanted to find out what things were good conductors of electric current. They built a circuit that could make a light bulb shine. They made sure their circuit worked. Then, they disconnected one wire. They placed different objects between the wire and the battery. See the picture for an example. They made this chart to show what they learned.

Item Tested	Did the bulb light? YES	NO
Pencil lead	X	
Paper clip	X	
Rubber band		X
Block of wood		X
Nail	X	
Plastic bottle cap		X

29. Based on their experiment, which things are good conductors?
    1. pencil lead, paper clip, nail
    2. rubber band, block of wood, plastic bottle cap
    3. All items were good conductors.
    4. None of the items were good conductors.
    5. There is not enough information given to tell.

30. Based on their experiment, which one of these things will probably <u>NOT</u> be a good conductor?
    1. metal screw
    2. penny
    3. pencil eraser

31. A group of three students were given the parts to build a circuit. Each student tried to build the circuit on his or her own. The pictures show what their circuits looked like. Which circuit would make the lamp light?

1. Insert I here 2. Insert J here 3. Insert K here

32. What part of the circuit pushes the electric current?
   1. battery
   2. switch
   3. wires
   4. lamp

33. What part of the circuit can control electricity by opening and closing the circuit?
   1. battery
   2. switch
   3. wires
   4. lamp

34. Sue and John built a funny looking flashlight. And, it worked! Which one of these pictures might be their flashlight?

1. Insert L here 2. Insert M here 3. Insert N here

35. The amount of energy used in a certain amount of time is called
   1. force.
   2. current.
   3. power.

36. What is a watt?
   1. a type of switch
   2. a unit for measuring power
   3. a safety device

37. What is a kilowatt hour?
   1. 100 watts used in one hour
   2. 100 watts used in 100 hours
   3. 1000 watts used in one hour
   4. 1000 watts used in 100 hours

38. What safety devices protect people from wires that get too hot by opening the circuit?
   1. fuses and circuit breakers
   2. cords and plugs
   3. conductors and insulators
   4. outlets and switches

39. It is dangerous to plug an electric machine into the outlet when your hands or feet are wet. What is the main reason?
   1. The plug will be slippery and hard to hold.
   2. The water on your hands or feet can let electricity into your body.
   3. You might fall and break the electric machine.

40-41. You must look at this picture and read how this device works to answer questions #40-#41.

Insert 0 here

The string (A) holds a rubber band (B) that is stretched out. A burning candle (C) will make the string break. When the string breaks, the rubber band snaps. This makes the toy car (D) roll forward.

6

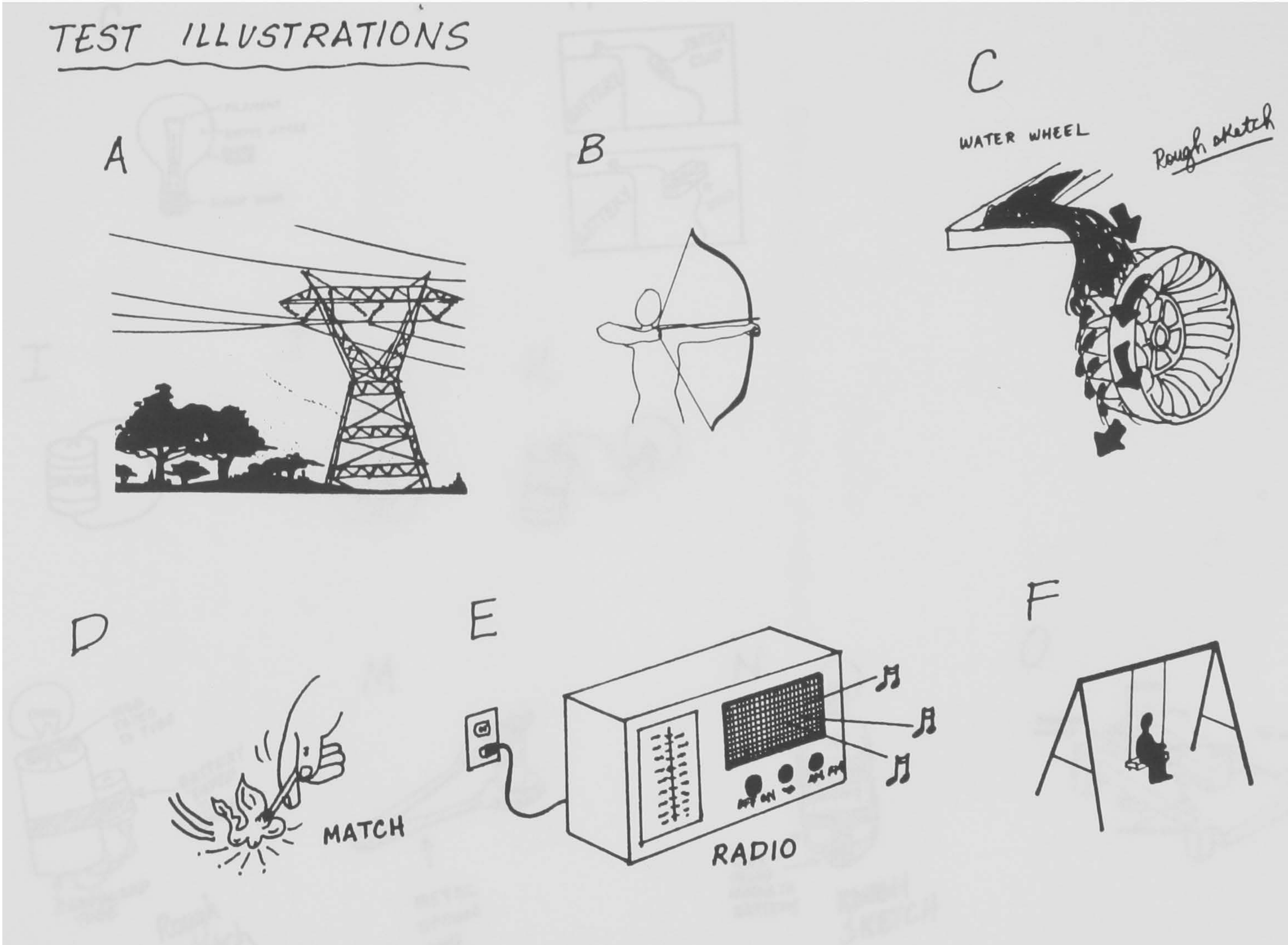
40. Which parts of this device have mechanical energy at <u>some point</u> during the time when this device is working?
    1. A, B, C, and D
    2. A, B, C
    3. B, C, D
    4. A, B, D
    5. B, D

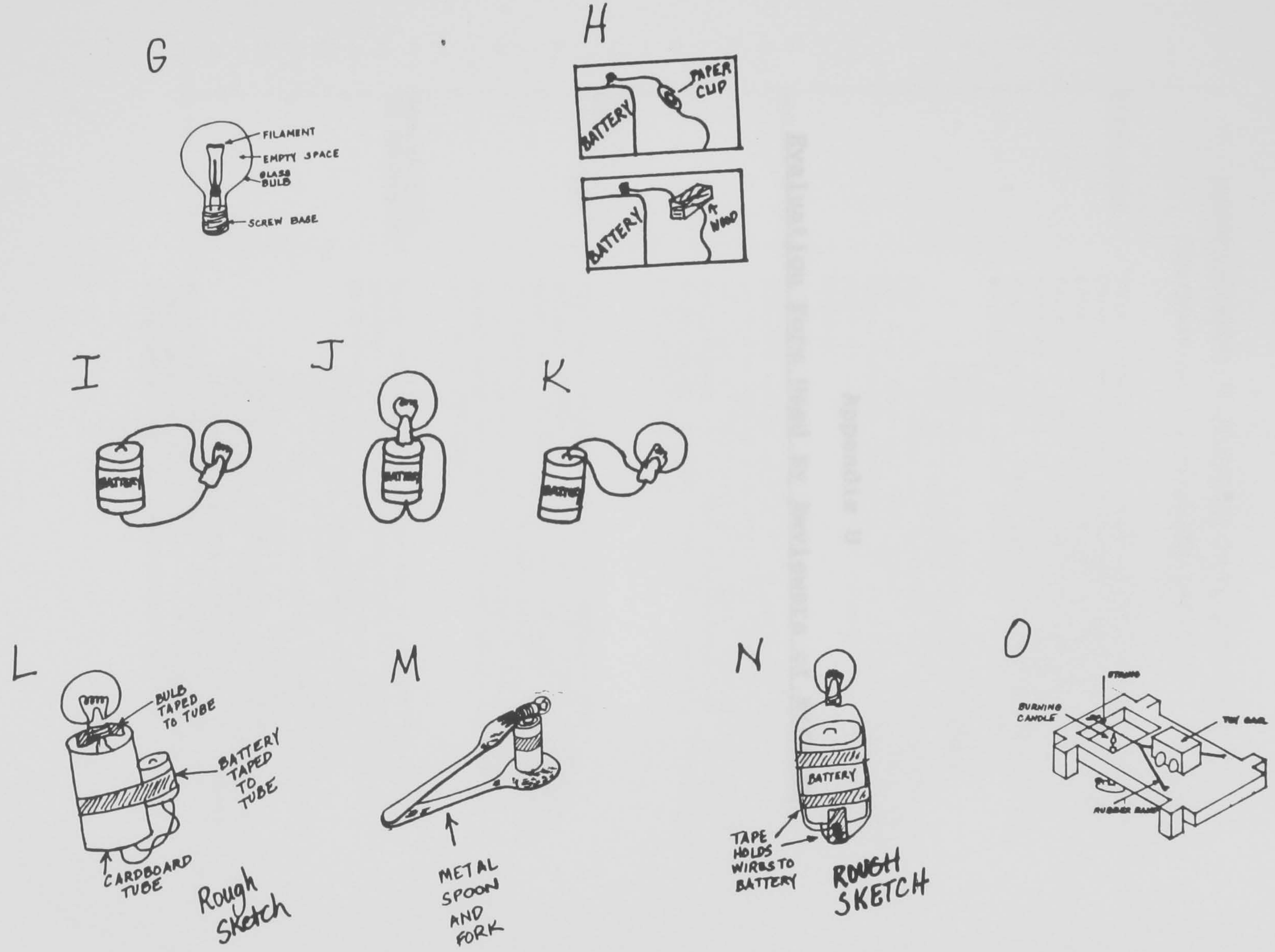
41. How can you <u>decrease</u> the potential energy of the rubber band?
    1. Use thick rope instead of string to hold the rubber band
    2. Stretch the rubber band tighter
    3. Don't stretch the rubber band so much
    4. Use a ball instead of a toy car

Check your answer sheet. Make sure that you only filled in one answer for each question.

When you finish, turn over your test and answer sheet. Wait until your teacher tells you what to do next.

10


TEST ILLUSTRATIONS
A
B
C
WATER WHEEL
Rough sketch
D
MATCH
E
RADIO
F


G
FILAMENT
EMPTY SPACE
GLASS BULB
SCREW BASE
H
PAPER CUP
BATTERY
WOOD
BATTERY
I
J
K
L
BULB TAPED TO TUBE
BATTERY TAPED TO TUBE
CARDBOARD TUBE
Rough Sketch
M
METAL SPOON AND FORK
N
BATTERY
TAPE HOLDS WIRES TO BATTERY
ROUGH SKETCH
O
STRING
BURNING CANDLE
TOY CAR
RUBBER BAND

Appendix U

Evaluation Form Used By Reviewers of WIKACFE

REVIEWER'S EVALUATION FORM

Science Knowledge Test

<u>Directions</u> *This form will be used to record your comments about the science knowledge test called, <u>What I Know About Changing Forms of Energy (WIKACFE)</u>. Carefully read the questions in the test booklet and fill out this form as you review each question. Each question must be evaluated in terms of three factors:*

- *Content*
- *Readability & format for 5th grade*
- *Type of knowledge tested*

Use the information provided below to guide how you evaluate and rate each item. Feel free to make lengthy comments by writing in the comment section on this sheet or anywhere on the test booklet.

<u>Rating CONTENT</u> *All test items were drawn from three lessons in the 5th grade textbook. A copy of those textbook pages are provided as well as an outline of the concepts. Rate content as either ACCEPTABLE (A) or NOT ACCEPTABLE (N). If not acceptable, please provide a comment to explain your point of view.*

<u>Rating READABILITY and FORMAT</u> *All test items should be readable and understandable to typical 5th grade students. Mark your suggestions for changes with regard to readability and format directly on the test. It will be assumed that these things were acceptable (in your opinion) wherever you do not note changes.*

<u>Rating TYPE OF KNOWLEDGE</u> *Each test item must be rated according to whether it tests it declarative knowledge or procedural knowledge. These are defined as:*

- ***<u>DECLARATIVE KNOWLEDGE</u>: factual or conceptual mastery of the subject; a test item is measuring students recall of specific facts or concepts***
- ***<u>PROCEDURAL KNOWLEDGE</u>: students' application of reasoning strategies to solving problems related to the subject***

Rate type of knowledge by marking a D (declarative knowledge) or P (procedural knowledge) in the appropriate column.

#	CONTENT A or N	TYPE OF KNOWLEDGE D or P	YOUR COMMENT
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			

#	CONTENT A or N	TYPE OF KNOWLEDGE D or P	YOUR COMMENT
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			

#	CONTENT A or N	TYPE OF KNOWLEDGE D or P	YOUR COMMENT
33			
34			
35			
36			
37			
38			
39			
40			
41			

Appendix V

Summary of Reviewers' Suggestions on WIKACFE

SUMMARY OF REVIEWERS' SUGGESTIONS ON WIKACFE

Feedback from each of the five reviewers of the MyPOV instruments differed considerably. The chart which follows synthesizes the comments provided by individual reviewers and displays how each reviewer categorized every test item. Each comment is prefaced with a number to indicate which reviewer made the comment. In addition, reviewer numbers are used in the Categorization columns.

Reviewer #5 chose to provide only very general comments about test items and did not want to categorize individual test items as measuring declarative knowledge or procedural knowledge. Hence, his comments are reflected in the general comments section and not in the categorization columns. Please refer to the draft test as seen reviewers in order to interpret these comments (appendix T).

(NOTE: Reviewer #2 is considered the greatest expert in categorizing items as declarative knowledge and procedural knowledge. Additional comments from him are shown at the conclusion of this summary.)

KEY FOR READING CHART

Reviewers

1: Mr. John G. Wells
2. Dr. George Glasson
3: Mr. Butch Morris
4: Ms. Ellen Harkrader
5: Dr. Robert Frary

Categories

D = Declarative Knowledge
P = Procedural Knowledge

#	COMMENTS		REVIEWERS' CATEGORIZATION OF QUESTIONS 1	2	3	4
1	5)	Reword question using specific examples instead of a vague definition.	D	D	D or P	D
2	1)	The energy in the movement of particles that...	D	D	D or P	D
	2)	Various forms of energy involve movement of particles (i.e., moving particles from splitting atoms; ions moving in water)				
	3)	Concept not elaborated on enough...unless prior knowledge; should be declarative but this question not supplied enough information so could be procedural				
3			D	D	D	P
4			D	D	D	P
5			D	D	D	D
6	2)	Flower could move	D	D	P	P
7	3)	Acceptable only if teacher provides more examples than what is in book and on unit plan	D	D	P	P
8			D	D	P	P

#	COMMENTS		REVIEWERS' CATEGORIZATION OF QUESTIONS 1	2	3	4
9	2)	#3 & #4 are both possible answer-- pushing swing will increase potential energy	P	D	P	P
	3)	Students won't have enough knowledge from what is indicated here to differentiate answers 3 & 4				
10	2)	Flower does not photosynthesize -- leaf does	D	D	P	P
11			D	D	P	P
12	2)	Why include "food"? -- aren't you testing for knowledge of energy changes?	D	D	P	P
13	2)	Confusing-I'm not sure this is covered in book -- electric energy in filament converts to radiant energy that passes through empty space & then through glass bulb	D	D	P	P
14	2)	I disagree with book -- thermal energy of steam changes to mechanical energy of turbine which changes to electric energy	D	D	D	P

#	COMMENTS		REVIEWERS' CATEGORIZATION OF QUESTIONS 1	2	3	4
15	2)	I'm not sure book adequately explains radiant energy	D	D	P	P
	3)	Just a gut reaction but this one will confuse based on preconcepts on all four items being vague because of complexity of systems				
16	2)	Battery is answer if you add "in a complete circuit"	D	D	P	P
17	2)	Are matter and energy the same thing? Then why two different terms?	D	D	P	D
	3)	Statistics show that negative logic is tricky with earlier stages of development -- also, matter full of alternative meanings!				
18			D	D	D	D
19	3)	Ambiguities with term "freely"	D	D	D	D
20			D	D	P	D
21			D	D	P	P
22	2)	What do you mean by push and pull?	D	D	D	D
23	1)	Electricity is the result of...	D	D	D	D

#	COMMENTS		REVIEWERS' CATEGORIZATION OF QUESTIONS 1	2	3	4
24			D	D	D	D
25			D	D	D	D
26	2)	Book does not explain what happens when electricity comes through the wires	P	D	P	P
27			D	D	D	P
28	2)	Electricity will flow through short circuit until it shorts out	D	D	D	D
29	2)	Students just need to know what a conductor is	P	D	P	P
30	2)	Pencil lead is not a metal...may have effect on how they answer the question (i.e., choosing answer #2: penny). I would use another metal example & omit pencil lead.	P	D	P	P
31	2) 3)	Label bulb on diagram Drawing is confusing	P	D	P	P

#	COMMENTS		REVIEWERS' CATEGORIZATION OF QUESTIONS 1	2	3	4
32	2)	Even though book uses "pushing" -- term is oversimplification -- to answer this would be pure memorization rather than understanding	D	D	D	D
	3)	Pushes has too many personal meanings				
33			D	D	D	D
34			P	D	P	P
35			D	D	D	D
36			D	D	D	D
37			D	D	D	D
38			D	D	D	D
39			P	D	P	D
40			P	D	P	P
41			P	D	P	P

<u>Other comments by Reviewer #2:</u>

It would be helpful if you could identify what specific reasoning strategies were used for your procedural knowledge questions (i.e., control of variables). Questions # 29, 30, 34, 40, and 41 could be procedural knowledge defined as <u>applications</u> of <u>knowledge</u> but most researchers would just call this declarative knowledge. Look in literature to see how Lawson defines & uses procedural knowledge...proportional reasoning, control of variables, correlational reasoning, probablistic reasoning, combinational reasoning. You might find other examples of how procedural knowledge was used or tested for in literature -- and then classify your questions accordingly. Also, you may want to move into a Bloom's taxonomy paradigm and classify your questions accordingly -- it is a "cleaner" connection (knowledge, comprehension, application...).

Appendix W

Field Test Version of the What I Know About Changing Forms of Energy Instrument (WIKACFE)

What I Know About Changing Forms of Energy

Your answers on this test will NOT affect your grades in this class.

DIRECTIONS:

1. All your answers must be filled in on the answer sheet provided.
2. You must use a #2 pencil. Your teacher will give you one if you don't have one.
3. Do not make any marks on the answer sheet except where you are told.
4. Mark only one answer for each question. Choose the BEST answer.
5. If are not sure of the answer, make a guess.

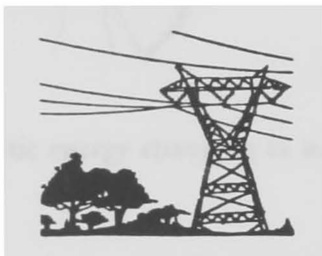
Do not turn the page until your teacher tells you to do so.

DON'T FORGET...MARK ALL YOUR ANSWERS ON THE ANSWER FORM.

1. Work takes place only when
   1. effort is used.
   2. energy moves an object.
   3. force is applied.
   4. matter changes forms.

2. The energy from the movement of the particles that form an object is called
   1. chemical energy.
   2. nuclear energy.
   3. radiant energy.
   4. thermal energy.

3. What kind of energy do power lines like the ones shown in this picture carry?



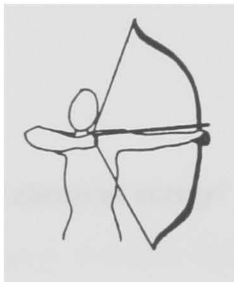
   1. nuclear energy
   2. electrical energy
   3. mechanical energy
   4. thermal energy

4. Hammering a nail and riding a bike are examples of
   1. chemical energy.
   2. radiant energy.
   3. mechanical energy.
   4. thermal energy.

5. What kind of energy is released when atoms are split or joined?
   1. chemical energy
   2. nuclear energy
   3. radiant energy
   4. thermal energy

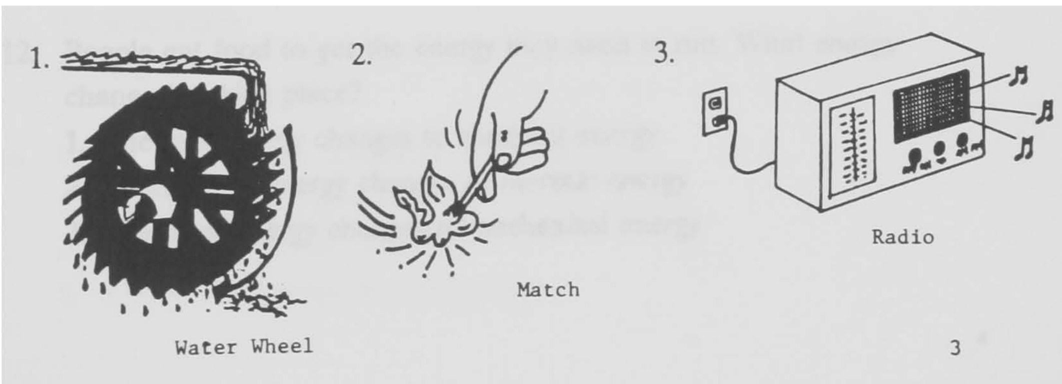
6. Which one of these is an example of kinetic energy?
   1. wind blowing leaves from the trees
   2. sunlight shining on a parked car
   3. a roof covered with snow

7. Look at this picture. The man is getting ready to shoot an arrow from his bow. He has pulled back the arrow as far as he can. What kind of energy does the arrow have now?



   1. kinetic energy
   2. potential energy
   3. no energy

8. Which picture shows one kind of **kinetic energy changing to another kind of kinetic energy**?



9. Look at this picture. The child is sitting on the swing. How could you increase the **potential mechanical energy** of the swing?

1. take the child off the swing
2. put a larger child on the swing instead
3. pull the swing back and hold it there

10. Which one of these things changes **radiant energy to chemical energy**?
    1. a leaf
    2. a lump of coal
    3. a battery
    4. a light bulb

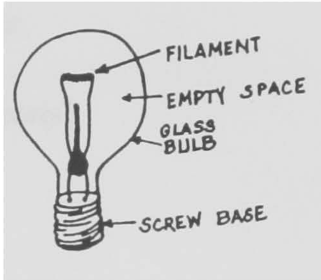
11. Which one of these things **releases chemical energy**?
    1. an electric stove
    2. water falling over a cliff
    3. burning oil or gas
    4. wind blowing the sails on a boat

12. People eat food to get the energy they need to run. What energy change is taking place?
    1. thermal energy changes to chemical energy
    2. mechanical energy changes to thermal energy
    3. chemical energy changes to mechanical energy

4

13. This is a picture of an ordinary light bulb. When this bulb is used in a lamp, where does **electric energy change to radiant energy**?

1. at the screw base
2. in the filament
3. in the empty space inside the glass bulb
4. in a special paint that coats the glass bulb



14. Which one of these things changes **electric energy** to **thermal energy** and then into **radiant energy**?
    1. electric motor
    2. toaster
    3. bicycle generator
    4. candle

15. Which one of these things could change **chemical energy** to **electric energy**?
    1. battery
    2. light bulb
    3. food mixer
    4. hair dryer

16. Which one of these statements is <u>**FALSE**</u>?
    1. Energy can change to matter.
    2. Matter can change to energy.
    3. Matter and energy can disappear.

5

17. What part of an atom has **no electric charge**?
    1. proton
    2. neutron
    3. electron
    4. They all have an electric charge.

18. What part of an atom can move freely?
    1. proton
    2. neutron
    3. electron
    4. None of them can move freely.

19. An atom is POSITIVELY charged when it has **more**
    1. neutrons than electrons.
    2. protons than neutrons.
    3. electrons than protons.
    4. electrons than neutrons.
    5. protons than electrons.

20. An atom has 2 protons, 2 neutrons, and 3 electrons. What charge does this atom have?
    1. negative charge
    2. positive charge
    3. no charge

21. If two atoms are NEGATIVELY charged, what will happen?
    1. They will push away from each other.
    2. They will pull together.
    3. They will push and pull causing a spark.

22. Electricity is the result of the movement of
    1. protons.
    2. neutrons.
    3. electrons.

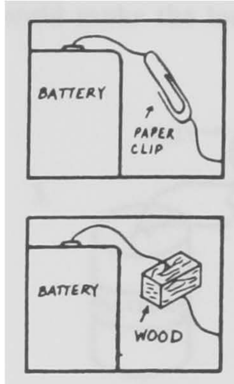
23. Things that allow electric current to **easily flow** through them are called
    1. insulators.
    2. conductors.
    3. generators.

24. Rubber, glass, and plastic are
    1. insulators.
    2. conductors.
    3. generators.

25. Which one of these devices changes **mechanical energy to electricity using a magnet**?
    1. dry cell battery
    2. wet cell battery
    3. generator

26. Electric current flows through a path called
    1. an open circuit.
    2. a closed circuit.
    3. a broken circuit.

27-28. Read about this experiment. Look at the picture and chart to answer questions #27-#28.



Experiment

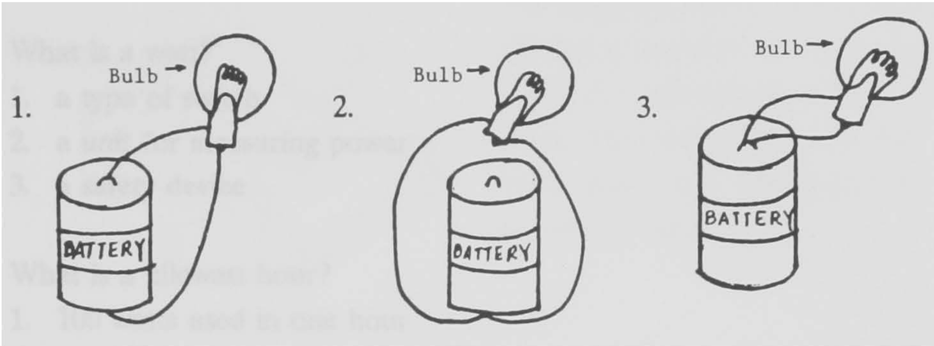
Tim and Pam wanted to find out what things were good conductors of electric current. They built a circuit that could make a light bulb shine. They made sure their circuit worked. Then, they disconnected one wire. They placed different objects between the wire and the battery. See the picture for two examples. They made this chart to show what they learned.

Item Tested	Did the bulb light? YES	NO
Aluminum foil	X	
Paper clip	X	
Rubber band		X
Block of wood		X
Nail	X	
Plastic bottle cap		X

27. Based on their experiment, which things are good conductors?
    1. aluminum foil, paper clip, nail
    2. rubber band, block of wood, plastic bottle cap
    3. All items were good conductors.
    4. None of the items were good conductors.
    5. There is not enough information given to tell.

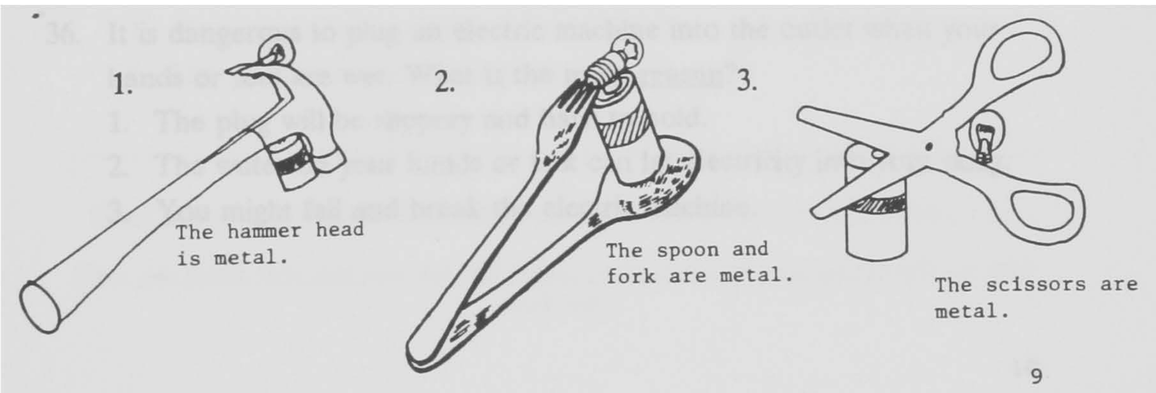
28. Based on their experiment, which one of these things will probably NOT be a good conductor?
    1. metal screw
    2. penny
    3. pencil eraser

29. A group of three students were given the parts to build a circuit. Each student tried to build the circuit on his or her own. The pictures show what their circuits looked like. **Which circuit would make the lamp light?**



30. What part of the circuit can control electricity by **opening and closing the circuit?**
    1. battery
    2. switch
    3. wires
    4. lamp

31. Sue and John built a funny looking flashlight. And, it worked! Which one of these pictures might be their flashlight?



32. The amount of energy used in a certain amount of time is called
    1. force.
    2. current.
    3. power.

33. What is a watt?
    1. a type of switch
    2. a unit for measuring power
    3. a safety device

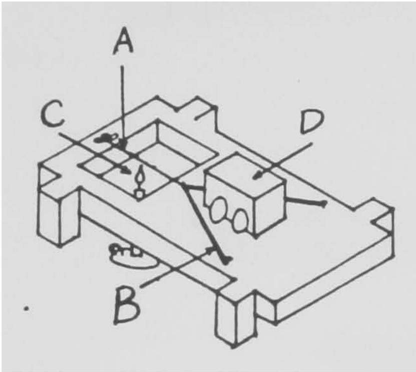
34. What is a kilowatt hour?
    1. 100 watts used in one hour
    2. 100 watts used in 100 hours
    3. 1000 watts used in one hour
    4. 1000 watts used in 100 hours

35. What safety devices protect people from wires that get too hot by opening the circuit?
    1. fuses and circuit breakers
    2. cords and plugs
    3. conductors and insulators
    4. outlets and switches

36. It is dangerous to plug an electric machine into the outlet when your hands or feet are wet. What is the <u>main reason</u>?
    1. The plug will be slippery and hard to hold.
    2. The water on your hands or feet can let electricity into your body.
    3. You might fall and break the electric machine.

10

37-38. You must look at this picture and read how this device works to answer questions #37-#38.



The string (A) holds a rubber band (B) that is stretched out. A burning candle (C) will make the string break. When the string breaks, the rubber band snaps. This makes the toy car (D) roll forward.

37. Which parts of this device have **mechanical energy** at some point during the time when this device is working?
    1. A, B, C, and D
    2. A, B, C
    3. B, C, D
    4. A, B, D
    5. B, D

38. How can you **decrease** the **potential energy** of the **rubber band**?
    1. Use thick rope instead of string to hold the rubber band
    2. Stretch the rubber band tighter
    3. Don't stretch the rubber band so much
    4. Use a ball instead of a toy car

Check your answer sheet. Make sure that you only filled in one answer for each question.

When you finish, turn over your test and answer sheet. Wait until your teacher tells you what to do next.

Appendix X

What I Know About Changing Forms of Energy
(WIKACFE) Instrument
With Teacher Instructions For Administering It

What I Know About Changing Forms of Energy

Your answers on this test will NOT affect your grades in this class.

DIRECTIONS:

1. All your answers must be filled in on the answer sheet provided.
2. You must use a #2 pencil. Your teacher will give you one if you don't have one.
3. Do not make any marks on the answer sheet except where you are told.
4. Mark only one answer for each question. Choose the BEST answer.
5. If are not sure of the answer, make a guess.

Do not turn the page until your teacher tells you to do so.

DON'T FORGET...MARK ALL YOUR ANSWERS ON THE ANSWER FORM.

1. Which of the following is an example of work taking place?
   1. a child pushes on a brick wall which does not move
   2. a ball is thrown at a lamp causing it to fall over
   3. sunlight shines through a window and warms a room
   4. a flashlight is left on and the battery wears out

2. The energy from the movement of the particles that form an object is called
   1. chemical energy.
   2. radiant energy.
   3. thermal energy.

3. What kind of energy do power lines like the ones shown in this picture carry?

   1. electrical energy
   2. mechanical energy
   3. thermal energy

4. One person is hammering a nail. Another person is riding a bike. What kind of energy do the hammer and bike have?
   1. chemical energy
   2. radiant energy
   3. mechanical energy
   4. thermal energy

2

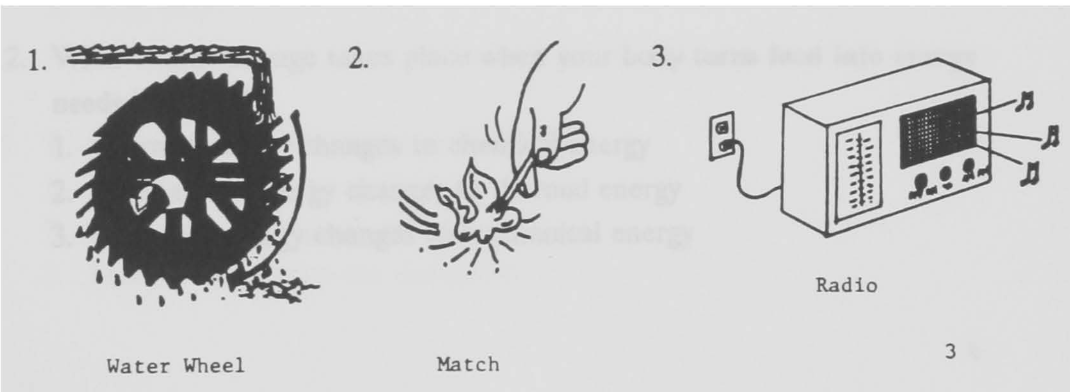
5. What kind of energy is released when atoms are split or joined?
   1. chemical energy
   2. nuclear energy
   3. radiant energy
   4. mechanical energy

6. Which one of these is an example of kinetic energy?
   1. wind blowing leaves from the trees
   2. sunlight shining on a parked car
   3. a roof covered with snow

7. Look at this picture. The man is getting ready to shoot an arrow from his bow. He has pulled back the arrow as far as he can. What kind of energy does the arrow have now?

   1. kinetic energy
   2. potential energy
   3. no energy

8. Which picture shows one kind of **kinetic energy changing to another kind of kinetic energy**?



9. Look at this picture. The child is sitting on the swing. How could you increase the **potential mechanical energy** of the swing?

1. take the child off the swing
2. put a larger child on the swing instead
3. pull the swing back and hold it there

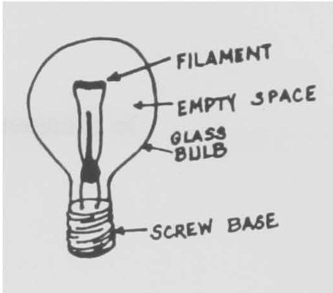
10. A plant leaf changes **radiant energy** from the sun **to**
    1. thermal energy.
    2. chemical energy.
    3. nuclear energy.
    4. mechanical energy.

11. Which one of these things **releases chemical energy**?
    1. an electric stove
    2. a wagon rolling down a hill
    3. burning oil or gas
    4. wind blowing the sails on a boat

12. What energy change takes place when your body turns **food into energy needed to run**?
    1. thermal energy changes to chemical energy
    2. mechanical energy changes to thermal energy
    3. chemical energy changes to mechanical energy

13. This is a picture of an ordinary light bulb. When this bulb is used in a lamp, where does **electric energy change to radiant energy**?

1. at the screw base
2. in the filament
3. in the empty space inside the glass bulb
4. in a special paint that coats the glass bulb



14. Which one of these things changes **electric energy** to **thermal energy** and then into **radiant energy**?
    1. electric motor
    2. toaster
    3. bicycle generator
    4. candle

15. Which one of these things could change **chemical energy to electric energy**?
    1. battery
    2. light bulb
    3. food mixer
    4. hair dryer

16. Which one of these statements is **<u>FALSE</u>**?
    1. Energy can change to matter.
    2. Matter can change to energy.
    3. Matter and energy can disappear.

5

17. What charge does a **neutron** have?
    1. positive charge
    2. negative charge
    3. no charge

18. Electricity is the result of the movement of
    1. protons.
    2. neutrons.
    3. electrons.

19. An atom has 4 electrons, 2 protons, and 2 neutrons. What charge does this atom have?
    1. negative charge
    2. positive charge
    3. no charge

20. One atom has a NEGATIVE charge. Another atom has a POSITIVE charge. What will happen if these atoms are near each other?
    1. They will push away from each other.
    2. They will pull together.
    3. They will push and pull until they spark.

21. Things that allow electric current to **easily flow** through them are called
    1. insulators.
    2. conductors.
    3. generators.

22. Rubber, glass, and plastic are good
    1. insulators.
    2. conductors.
    3. generators.

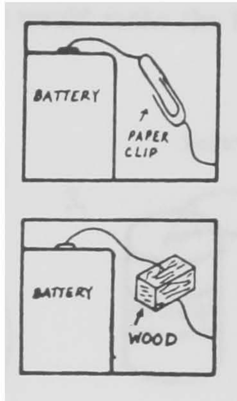
23. Which one of these devices changes **mechanical energy to electricity using a magnet**?
    1. battery
    2. fuse
    3. circuit breaker
    4. generator

24. A television is plugged into the wall. The switch is turned on. The television comes on. What kind of circuit is this?
    1. a closed circuit
    2. an open circuit
    3. a broken circuit.

25. Where would you most likely find a **wet cell battery**?
    1. in a radio alarm clock
    2. in a flashlight
    3. in a car
    4. on a bicycle

26. You just made a paper airplane. You want it to fly fast and far. Which one of these would probably affect your airplane's **kinetic energy**?
    1. weight
    2. shape
    3. wind conditions
    4. weight, shape, and wind conditions

27-28. Read about this experiment. Look at the picture and chart to answer questions #27-#28.



<u>*Experiment*</u>

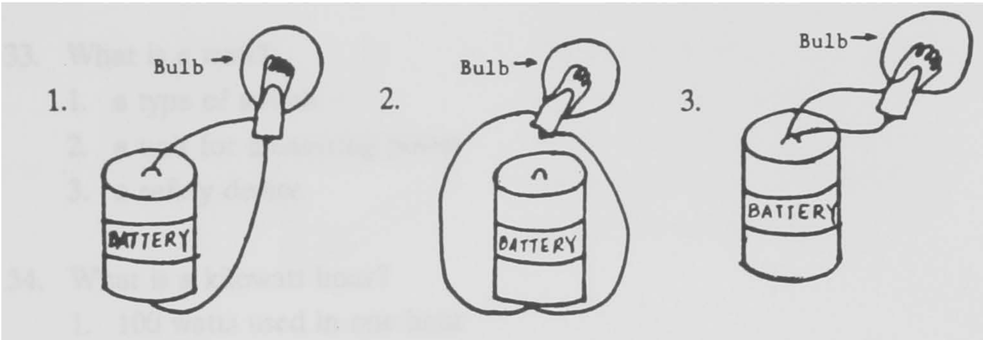
Tim and Pam wanted to find out what things were good conductors of electric current. They built a circuit that could make a light bulb shine. They made sure their circuit worked. Then, they disconnected one wire. They placed different objects between the wire and the battery. See the picture for two examples. They made this chart to show what they learned.

	Did the bulb light?	
Item Tested	**YES**	**NO**
Aluminum foil	X	
Paper clip	X	
Rubber band		X
Block of wood		X
Nail	X	
Plastic bottle cap		X

27. Based on their experiment, which things are good conductors?
    1. aluminum foil, paper clip, nail
    2. rubber band, block of wood, plastic bottle cap
    3. All items were good conductors.
    4. There is not enough information given to tell.

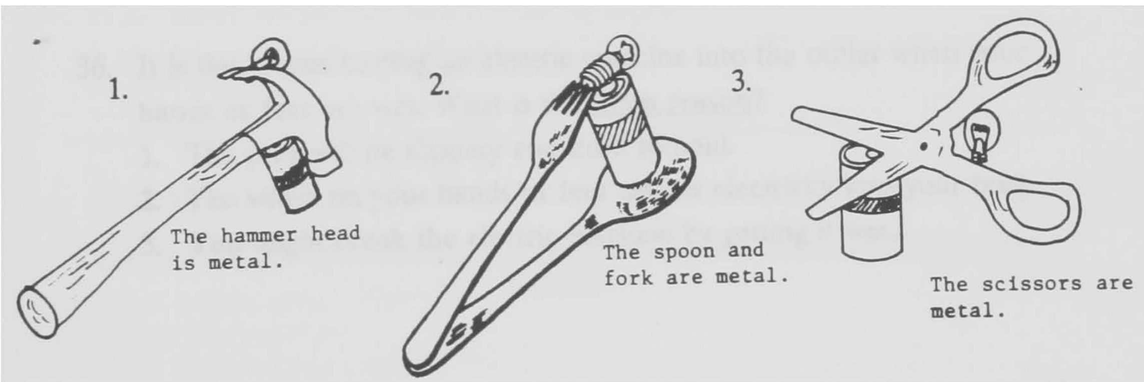
28. Based on their experiment, which one of these things will probably <u>NOT</u> be a good conductor?
    1. empty soda can
    2. penny
    3. pencil eraser

29. A group of three students were given the parts to build a circuit. Each student tried to build the circuit on his or her own. The pictures show what their circuits looked like. **Which circuit would make the lamp light?**



30. What part of the circuit can control electricity by **opening and closing the circuit?**
    1. battery
    2. switch
    3. wires
    4. lamp

31. Sue and John built a funny looking flashlight. And, it worked! Which one of these pictures might be their flashlight?



9

32. The **amount of energy** used in a **certain amount of time** is called
   1. power.
   2. electric force.
   3. work.

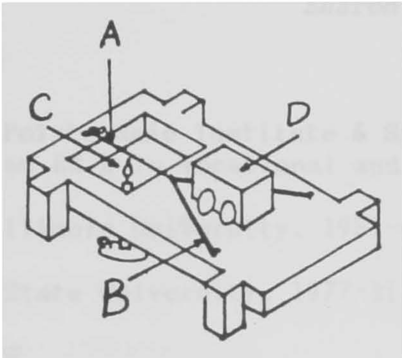
33. What is a watt?
   1. a type of switch
   2. a unit for measuring power
   3. a safety device

34. What is a kilowatt hour?
   1. 100 watts used in one hour
   2. 100 watts used in 100 hours
   3. 1000 watts used in one hour
   4. 1000 watts used in 100 hours

35. Which one of these things is a special safety device? It opens the circuit when too much current is flowing through it.
   1. fuse
   2. plug
   3. insulator
   4. conductor

36. It is dangerous to plug an electric machine into the outlet when your hands or feet are wet. What is the **main reason**?
   1. The plug will be slippery and hard to hold.
   2. The water on your hands or feet can let electricity into your body.
   3. You might break the electric machine by getting it wet.

37-38. You must look at this picture and read how this device works to answer questions #37-#38.



The string (A) holds a rubber band (B) that is stretched out. A burning candle (C) will make the string break. When the string breaks, the rubber band snaps. This makes the toy car (D) roll forward.

37. Which parts of this device have **mechanical energy** at <u>some point</u> during the time when this device is working?
    1. A, B, C, and D
    2. A, B, C
    3. A, B, D
    4. B, D

38. How can you <u>decrease</u> the **potential energy** of the **rubber band**?
    1. Use thick rope instead of string to hold the rubber band
    2. Stretch the rubber band tighter
    3. Don't stretch the rubber band so much
    4. Use a ball instead of a toy car

<u>Check your answer sheet. Make sure that you only filled in one answer for each question.</u>

<u>When you finish, turn over your test and answer sheet. Wait until your teacher tells you what to do next.</u>

Vita
of
Sharon A. Brusic

EDUCATION

Virginia Polytechnic Institute & State University, 1987-Present, Pursuing an Ed.D in Vocational and Technical Education

Eastern Illinois University, 1981-82, MS in Technology Education

Illinois State University, 1977-81, BS in Industrial Education

EXPERIENCE

Research Associate, 1989-90
Virginia Polytechnic Institute and State University
Blacksburg, VA
Responsibilities included:
- Authoring 8 children's books covering various technology topics (grades 3-6)
- Editing two interdisciplinary teachers' resource guides for the Mission 21 Project (grades 3-6) aimed at helping teachers to integrate technology education with other subjects

Graduate Research Associate, 1987-89
Virginia Polytechnic Institute and State University
Blacksburg, VA
Responsibilities included:
- Writing an interdisciplinary teacher's resource guide (grades 5-6) aimed at helping teachers to integrate technology education with other subjects
- Monitoring and supervising 13 fifth and sixth grade teachers who were field testing Mission 21 materials
- Planning and conducting workshops for field test teachers
- Giving presentations about the Mission 21 Project at various local, state, and national meetings

Assistant Professor, 1984-87
Kent State University
School of Technology, Kent, OH
Responsibilities included:
- Teaching courses in graphic communications, engineering graphics, elementary technology education, and technology teacher preparation
- Maintaining the graphic communications laboratory
- Coordinating summer technology programs at the university for children aged 6-15

Instructor and Research Associate, 1982-84
Illinois State University
Department of Industrial Technology, Normal, IL
Responsibilities included:

- Teaching courses in graphic communications and industrial arts teacher preparation
- Assisting the project director of the Illinois Plan for Industrial Education Project
- Gathering data from schools testing Illinois Plan curricula
- Writing and revising curriculum for technology programs in grades 6-10

Graduate Assistant, 1981-82
Eastern Illinois University
School of Technology, Charleston, IL
Responsibilities included:

- Team teaching a pilot program course in communication technology at Mattoon High School, Mattoon, IL
- Developed curriculum model and course materials for the Illinois Plan for Industrial Education Project

OTHER EDUCATIONAL ACHIEVEMENTS AND ACTIVITIES

- Wrote five chapters in a commercially-published textbook for technology education
- Developed or consulted on technology education curriculum in four states (Illinois, Ohio, Texas, Virginia)
- Member of the *Virginia Technology Education Association, International Technology Education Association, Technology Education For Children Council, Council on Technology Teacher Education, National Science Teachers Association, Phi Kappa Phi*, and *Phi Delta Kappa*

Sharon A. Brusic