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DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in The Ohio State University College of Education

By

Christopher P. Merrill, M.S. Ed., B.S. Ed.

* * * * *

The Ohio State University

2000

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ABSTRACT

Little research has been conducted at the high school level, which assesses the effect that an integrative approach to teaching and learning technology, mathematics, and science education together has on student learning. There are various theories regarding the educational worth of integrated approaches to teaching and learning. Theorists also offer suggestions for how to overcome implementation barriers at the secondary level that currently impede integration. Further, there seems to be consensus that assessment tools have not been developed to measure student learning when teachers are utilizing integrated approaches in their classrooms.

A quasi-experimental nonequivalent control group design was utilized for this research study. The researcher used six intact technology education classes in a small suburban village high school for this research study. Three classes were assigned to the treatment groups and the remaining three classes became comparison groups. The research protocol utilized six different instructional lessons on energy and power technology. The treatment groups were taught using an integrated curriculum focusing on technology, mathematics, and science education through a constructivist philosophical approach to teaching and learning. As part of the research protocol, the treatment groups utilized hands-on activities to reinforce the content they received. The comparison groups received equivalent curricular content, but were not taught in an integrated
fashion: constructivism was not a philosophical approach guiding this method of teaching; nor were students applying the content they received with hands-on activities.

Three hypotheses were tested in this research study. The researcher found no significant differences at the .05 alpha level between the treatment and comparison groups on (1) improved posttest scores after the treatment took place; (2) retention scores two and four weeks after the treatment; or (3) the number of open-ended terms/phrases that were completely integrated.

It was concluded that the treatment did not have a statistically significant effect on student learning immediately following implementation; the treatment did not have a statistically significant effect on the integration orientation of students; and the treatment did not have a statistically significant effect on the retention of student learning two and four weeks following implementation.
I dedicate this dissertation research study to my wife Kelli and daughter Rebecca. Kelli, without your love, support, faith, and willingness to leave our families and lifestyle for this three-year period, this study, along with a completed Ph.D. program, could not have been possible – Thanks! For you Rebecca, I dedicate this dissertation research in hope that some day you will reach your goals. You both mean the world to me.
ACKNOWLEDGMENTS

I wish to thank my adviser, Dr. Michael Scott for his guidance, wisdom, and professional discussions during this dissertation research study, without your help none of this would have been possible.

I am grateful to Dr. Janet Henderson for the unselfish amount of time she spent with me discussing, running, and analyzing data. You made this portion of the dissertation research study both interesting and manageable while still keeping my stress level down.

I wish to thank Dr. Paul Post for all the help with the energy bicycle and his guidance and wisdom throughout this process.

I would also like to thank Dr. Paul Vellom for his guidance and wisdom throughout this process.

Last, but certainly not least, I wish to acknowledge my family. Although at times you did not understand why this degree was so important, you kept believing and praying for success. In fact, some of you probably thought I wanted to be a professional student. Well, I have reached this terminal degree and I have all of you to thank for it. This degree, however, is not for me, but for each of you!
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CHAPTER 1

INTRODUCTION

The idea of an integrated curriculum or the integrating of various curricular concepts is not new to education or the fields of mathematics, science, and technology education. History reveals that some curriculum integration between these fields began as early as the 1800s with Calvin Woodward (Bennett, 1937). Woodward, who initiated the manual training movement in the United States (1837-1914), was a Professor of Mathematics at Washington University, located in St. Louis, Missouri. Woodward found that students in his mathematics classes could not visualize or conceptualize the theory and application of mathematics. In order for Woodward's students to learn, he took them to the woodworking/cabinetmaking shop (lab) where his students learned first-hand how to apply the theory of mathematics into workable objects. In addition to putting theory into practice, these students increased their knowledge and skill of tool processes (Bennett, 1937). Historical analysis further reveals curriculum integration in the general scope and sequence of education (Dewey, 1938, 1944; Dubins, 1957; Fuller, 1942; Goodlad, 1964; Gorman, 1943; Hopkins, 1941; Koestler, 1967; Kolb, 1967; Kuhlman, 1966; Mayhew, 1958; Moore, 1902; Payne, 1957; Rasmussen, 1964).
The integration of technology, mathematics, and science education has been gaining attention throughout each of the prospective fields as of late, especially at the middle school level. However, little research has been conducted at the high school level to probe whether an integrative approach to teaching and learning technology, mathematics, and science education together is valid and worthwhile or has an improvement on student learning. Wicklein and Schell (1995) stated “The question of educational worth has not been determined with any degree of accuracy. The question still remains, is the integration of mathematics, science, and technology education a step in the right curricular direction?” (p. 59). Foster (1994) stated that “Perhaps we [technology education] find M/S/T [math/science/technology] attractive insofar as it allows us to associate with what we aspire to be” (p. 78). Moreover, various barriers at the secondary level seem to have an effect on the implementation of an integrated approach to teaching and learning (Bergstrom, 1998; Grossman & Stodolsky, 1995; Lounsbury, 1996; McCarthy, 1988;). In addition, there has been no formal assessment tool to measure whether students have an improved learning effect due to an integrative format of teaching and learning. Mason (1996) when discussing past and present school curriculum stated:

Many believe the traditional curriculum fails to meet the needs of students in a complex, technologically advanced, interdependent world. The metaphor of the school as a **hallway** in which students pass from classroom to classroom to receive specialized instruction in isolated school subjects recalls the factory system that provided a model for the development of the comprehensive school a century ago. (p. 264)
In *Technology A National Imperative* (1988), a report by the International Technology Education Association (ITEA), the authors contend that learning should be “based on the concept that the school ought to be the setting where the student can pull all the parts (academic disciplines) together in the context of reality and the world beyond the school” (p. 11). One should not view the school as a factory system where students receive isolated instruction; however, in most cases, this is exactly what is happening. The integration of technology, mathematics, and science education, therefore, is an approach to bridge the gap between the isolation of parts. The American Association for the Advancement of Science (1993) in their call for school reform stated the following:

Reform must be comprehensive and long-term, if it is to be significant and lasting. It must center on all children, all grades, and all subjects. In addition, it [the reform] must deal interactively with all aspects of the system – curriculum, teacher education, the organization of instruction, assessment, materials, and technology, policy, and more. (Project 2061, p. XII)

In 1991, The Secretary’s Commission on Achieving Necessary Skills (SCANS) published a letter to parents, employers, and educators in the United States. This letter, which is a synopsis of the complete SCANS Report, provided one rationale for proposing and implementing a new approach to teaching and learning, which the researcher has inferred to be curriculum integration. “We are failing to develop the full academic abilities of most students and utterly failing the majority of poor, disadvantaged, and minority youngsters” (SCANS, 1991, p. 3). The Scans Report identified five competencies and a three-part foundation of skills that are needed in today’s schools. The competencies were resources, interpersonal skills, information, systems, and
technology. The three foundation skills were basic skills, thinking skills, and personal qualities (SCANS, 1991).

The National Commission on Excellence in Education published *A Nation at Risk: The Imperative for Educational Reform*. Through the observations and analysis that were made in developing this publication, several problems were identified, one of which can be construed as another rationale for curriculum integration. "Some worry that schools may emphasize such rudiments as reading and computation at the expense of other essential skills such as comprehension, analysis, solving problems, and drawing conclusions" (1983, p. 10). Much can be learned about education and U.S. schools through the SCANS Report and *A Nation at Risk*. However, a special report dealing with higher standards for high school graduates issued by The American Federation of Teachers (AFT) (1997) does not reflect the sentiments above. The AFT selected the following mission for U.S. schools: "The primary mission of schools should be to teach students how to read literature, write persuasively, solve tough mathematical problems, understand and appreciate history, and apply scientific principles in their everyday lives" (p. 8). There is no mention about the applicability of the curriculum or other reform initiatives that were posed in *A Nation at Risk* and the SCANS Report.

In 1983, the Carnegie Foundation released its report on the status of American schools. This report also had dramatic influence on the field of education, especially the implementation of technology education. This report is also in direct opposition to that of the American Federation of Teachers view on the mission of education. Boyer (1985) stated "We insist that students, teachers, administrators, and parents should have a shared vision of what, together, they are to accomplish" (p. 3).
Boyer, two years earlier had stated:

The globe has changed. If the high schools are to educate students about their world, new curriculum priorities must be set. If a school district is incapable of naming the things it wants high school graduates to know, if a community is unable to define the culture it wants high school graduates to inherit, if education cannot help students see relationships beyond their own personal ones, then each new generation will remain dangerously ignorant, and its capacity to live confidently and responsibly will be diminished. (1983, p. 95)

The thought and process of integrating other disciplines with technology education primarily emerged in the early 1970s (Maley, 1973) and has continued to be a topic of discussion today (NRC, 1985; Gloeckner, 1991; Daugherty & Wicklein, 1993; Foster, 1994; Wicklein & Schell, 1995; etc.). Recent programs, projects, and studies dealing with the integration of technology, mathematics, and science education (TMaSe) are also present in the literature (Brusic, 1991; Childress, 1996; LaPorte & Sanders, 1993, 1995; Loepp, 1991; Scarborough, 1994, 1993a, 1993b).

**Statement of the Problem**

The integration of technology, mathematics, and science education at the secondary level, taught by either a team of teachers or a single teacher from technology, mathematics, or science education is a growing national and international curricular and methodological concern. Past and current research has not clearly indicated how to measure the educational worth of an integrated approach to teaching and learning; how to overcome implementation barriers at the secondary level; nor has an assessment tool been developed to measure student learning using an integrated approach.
**Need and Purpose for the Study**

Technology, mathematics, and science education studies have been conducted at the middle school level (Brusic, 1991; Childress, 1996; IMaST, 1991, LaPorte & Sanders, 1993) but there has been no study conducted at the secondary level dealing directly with the integration of mathematics, science, and technology education as a curriculum content organizer. Scarborough (1993a, 1993b, 1994), however, completed research at the high school level, but the primary reasons were not to use technology, mathematics, and science education integration as a content organizer, but to examine curricular areas to improve science aptitude. The researcher, therefore, found it necessary to propose, construct, and implement a study focusing on technology, mathematics, and science education as a curriculum content organizer at the secondary level of education; an additional approach to probe constructivism, brain-based learning, and curriculum integration to further examine the magnitude and scope of this integrated teaching and learning approach. The researcher felt if a study such as this was conducted in the public arena, then the learning outcomes could provide additional knowledge of integrated teaching and learning. The purpose, of this study, therefore, was to investigate constructivism and brain-based learning in technology, mathematics, and science education curriculum integration through scientific testing in the public arena. Furthermore, these outcomes may help technology educators in developing and implementing an integrated approach in their classrooms.
Objectives of the Study

The following objectives guided this research study:

1. Provide the background, analysis, and evaluation of the methodological, theoretical, and philosophical underpinnings of technology, mathematics, and science education curriculum integration at the high school level;

2. Design and construct hands-on, minds-on activities that focus on and address the mapped national standards in each of three prescribed disciplines;

3. Address selected content and knowledge with an application of an integrated approach to teaching and learning technology, mathematics, and science education;

4. Assess how students view the relationships between and among technology, mathematics, and science education.

Research Questions

Varying positions on the integration of curriculum in U.S. schools needs to be researched in the public arena – a chance to probe the theory and philosophy surrounding integrated curriculum. The major questions of this research study were:

1. Does the teaching of high school level integrated technology, mathematics, and science education content and activities, in conjunction with mapped national standards in each of the three subject areas and taught by technology education teachers in technology education laboratories, have an immediate cognitive learning effect and do students have long-term learning retention on technological, mathematical, and scientific problems?
2. How do students view the relationship between mathematical constructs and technology education?

3. How do students view the relationship between scientific constructs and technology education?

4. How do students view the relationship between technological constructs and mathematics and science education?

5. Is retention of content improved over a long-term period through an integrated teaching and learning approach?

Research Hypotheses

The research hypotheses for this research study were:

1. High school students who are engaged in integrated technology, mathematics, and science education curricula taught by a technology education teacher, would have an increased cognitive learning effect as compared to high school students not receiving an integrated curricula in technology, mathematics, and science education as measured by the mean score on the integrated energy and power technology posttest instrument.

2. Subjects participating in the integrated curricula approach would identify more terms, phrases, and examples of how technology, mathematics, and science are connected in real-world constructs, than those subjects not receiving an integrated curricula approach, as measured by the frequency of terms, phrases, and examples on the posttest instrument.

3. Subjects participating in the integrated curricula approach would have an increase in content retention two and four weeks after the study has been completed, as measured
by the mean score on the posttest retention instrument, than those students not receiving an integrated curricula approach.

**Research Procedures**

A high school located in a small suburban village in the United States was purposefully chosen to take part in this research study. The high school has an approximate enrollment of 225 students. From these 225 students, a purposive sample of 71 students who were currently enrolled in technology education classes were used as research subjects. The research study utilized intact technology education classes and took place in the normal technology education classrooms/laboratories at this high school. The technology education teacher was trained by the researcher to teach the experimental and comparison protocols for this study. The high school chosen for this research study bases its school structure/curriculum on block scheduling. Instead of having six or seven 50-minute periods in a single school day, classes are arranged on an A/B schedule. On Monday of each week, the school day has both A and B classes that meet for 43 minutes each. Tuesday and Thursday are A days while Wednesday and Friday are B days. Three classes meet on the A days and three classes meet on the B days. Each class meets for 85 minutes. The seventy-one subjects that took part in this research study comprised six classes. The total number of contact minutes per week was 213.

The data collection took approximately six weeks. Each of the six classes were randomly assigned to either the experimental or comparison groups. On the first day (Monday), each class received the pretest. Following the pretest, the experimental groups received six different curricular lessons on integrated technology, mathematics, and
science education using hands-on activities and the constructivist approach to teaching and learning. The comparison groups also received six curricular lessons.

Both the experimental and comparison groups were instructed using the same curriculum. However, the comparison groups did not receive the integrated, hands-on activity based constructivist approach, but activities in the form of workbook lessons. At the conclusion of the second week, each group was post tested. Two weeks after the conclusion of the study, the comparison and experimental groups were post tested on retention. Two weeks after the posttest on retention, both groups were post tested again on retention.

Assumptions

This study was predicated upon the following assumptions:

1. The subjects selected for this study were representative of secondary school students in the United States.

2. The technology education program involved in this study was representative of secondary school technology education programs in the United States.

3. The technology education teacher involved in this study was representative of technology education teachers in the United States.

4. Subjects participating in this study have a range of cognitive abilities.

5. Subjects participating in this study have been exposed to ninth grade technology education curricula before this study.

6. Subjects participating in this study have been exposed to ninth grade mathematics education curricula before this study.
7. Subjects participating in this study have been exposed to ninth grade science education curricula before this study.

8. The curriculum and activities for this study were appropriate for secondary school students.

9. Instructional materials were written at the ninth grade level to help ensure student readability.

10. Student scores on all pretest, posttest, and retention measures were representative measurements of their achievement.

**Limitations**

The following limitations of this study are acknowledged:

1. The integrated teaching and learning curriculum was taught by one technology education teacher, and thus does not represent full-integrated teaching and learning.

2. The integrated teaching and learning curriculum study was completed at one high school in the United States. Additional data and outcomes could have possibly been reached if this research protocol was completed in additional high school settings.

3. Costs of making and transporting the Pedal 4 Power Energy Education Bicycle. The energy bicycle cost $3,000 to produce, in addition to transportation expenses.

4. The limited time this research study was completed. The research protocol was six weeks in length, and thus did not allow for in-depth curriculum integration inferences.

5. The official standards for technology education (Standards for Technological Literacy: Content for the Study of Technology) were not released until April 2000. The researcher could have more closely tied these standards to the mathematics and science standards, which may have resulted in better curricular material.
Definition of Terms

For this study, the following terms were operationally defined from the research questions:

1. **Integrated Technology, Mathematics, and Science Education Content**

   A six-part energy and power technology curriculum implemented in technology education classes at the secondary level which naturally brought together technology, mathematics, and science education into a coherent, educative teaching and learning format.

2. **Technology Education**

   The place in the high school curriculum where students are taught about the systems of technology through a hands-on, minds-on approach to teaching and learning.

   **Technology Education Laboratories**

   A production/manufacturing laboratory comprised of industrial tools and equipment where students apply content in real-world situations, and a design/graphics laboratory where students used various communication technologies to solve technological problems.

3. **Standards**

   A mathematical, scientific, and technological benchmark of type that explains *where* (specific grade level – 9 thru 12) in their education students will learn integrated teaching and learning content, *what* content is to be taught and learned by the students (integrated technology, mathematics, and science education), and *how* students will learn and perform this content (by engaging in curriculum content and activities).
4. **Activities**

Hands-on and workbook type questions/problems students will partake in to reinforce the integrated and non-integrated energy and power technology curriculum.

5. **Mapped**

Content (energy and power) and activities (hands-on and workbook type questions/problems) that will be measured by technology, mathematics, and science education standards to reinforce the curriculum in each of the three subject areas.

6. **Retention**

The maintenance of learning as measured by a posttest (retention) instrument given two and four weeks after the original administration of the posttest.

7. **Learning Effect**

The change in cognitive knowledge as measured by an increase or decrease on the posttest technology, mathematics, and science education instrument.
CHAPTER 2

REVIEW OF RELATED LITERATURE

The literature review is not a compilation of facts and feelings, but a coherent argument that leads to the description of a proposed study... By the end of the literature review, the reader should be able to conclude that, 'Yes, of course, this is the exact study that needs to be done at this time to move knowledge in this field a little further along'. (Rudestam & Newton, 1992, p. 47)

This review of literature encompasses many concepts and constructs regarding curriculum integration, mathematics, science, and technology education. The researcher's attempt was to provide the reader(s) with objective information regarding integration and educational reform in the best scholarly manner. The following pages will reveal research on learning theories, curriculum integration, technology, mathematics, and science education, and how standards have influenced educational change.

Curriculum Integration

In the traditional high school, the school day consists of a set of classes that students enroll in and attend. This attendance or contact time generally ranges from as little as forty minutes to as long as two hours per class, per day. The researcher
concluded that some contact hours are longer or shorter, and block scheduling is also prevalent in today's high schools. Generally, however, the normal contact time per class is fifty minutes. During this time, students are predominately engaged in one curricular area, e.g., mathematics. Jacobs (1989a) in her study on integrated curricula stated:

A common concern of students is the irrelevance of their course work in their lives out of school. They find it difficult to understand why they need math when most of their instruction is based on a textbook used in isolation from its applications. (Jacobs, 1989a, p. 4)

The case of a specific discipline is not the issue, but rather the lack of trying to connect what the student is learning to other contextual areas, i.e., science and technology education. "There is a need to actively show students how different subject areas influence their lives, and it is critical that students see the strength of each discipline perspective in a connected way" (Jacobs, 1989a, p. 5). Pring (1973) noted that "The very notion of 'integration' incorporates the idea of unity between forms of knowledge and the respective disciplines" (p. 135).

There are several reasons why today's school system, especially at the high school level does not have an integrative approach to teaching and learning. These reasons include, but are not limited to: efficiency, state goals, standardized testing, teacher-based tests, supplementary materials, and the fact that each discipline provides specialized skills and concepts directly related to the content (Jacobs, 1989b). A problem with this approach [stand alone curriculum areas] to teaching and learning is the concept of fragmentation. The students have seven or eight fragmented periods of study per day with little or no chance to make sense of the totality of their education.
Integrating the curriculum is a renewed approach to teaching and learning that more closely resembles how people learn and work in the real world. The belief that “the whole is more than the sum of the parts” is a powerful curriculum movement that is helping children make learning connections. (Kotar, Guenter, Metzger, & Overholt, 1998, p. 43)

There are several broad dimensions to curriculum integration: (1) the curriculum is organized around the real world; (2) pertinent knowledge is organized without regard to subject area lines; (3) learning is not based on an eventual test, but rather the content; and (4) real application and problem solving are used to connect the content to real world applications (Beane, 1996). Each school examining curriculum integration will probably approach teaching and learning a little differently which is acceptable because no two schools are identical. If a school considering curriculum integration were to use the four broad dimensions of curriculum integration mentioned above to start the process of change, one could only think of the possible connections and reality-based education that students would receive. Regardless of the teaching and learning framework, “The focus should be on designing a curriculum that is relevant, standards based, and meaningful for students. At the same time, the curriculum should challenge students to solve real world problems” (Loepp, 1999, p. 21).

In addition to the broad curricular dimensions stated above, Loepp (1999) provided three different curriculum models that could be implemented in the classroom for curriculum integration purposes: (1) the interdisciplinary model; (2) the problem-based model; and (3) the theme-based model. In the interdisciplinary model, according to Loepp “schools group traditional subjects into blocks of time, assign a given number
of students to a team of teachers, and expect the teachers to deliver an interdisciplinary or integrated curriculum" (p. 22).

In practice, this model is being used with greater and greater frequency at the middle school level. This model offers several advantages: Teachers are given time to work together, they have a limited number of students, and this model can support a traditional curriculum while offering scheduling flexibility to the team. (Loepp, 1999, p. 23)

The second model that Loepp referred to was the problem-based model. In this model, a "problem" is placed in the center of a circle. Teachers then use a type of webbing technique to incorporate other learning areas of the curriculum to help solve the problem. This model represents a real-life scenario of how teachers and students alike address problems in a real-world approach; drawing upon all the disciplines. "An advantage of this model of integration is that it offers high potential for the identification of relevant, highly motivating problems" (Loepp, 1999, p. 23). The Technology, Science, and Mathematics (T/S/M) Integration Project developed by LaPorte and Sanders (1996) based its integration on this model.

The third model that Loepp (1999) referred to was the theme-based model. Like the name of this model suggests, a theme is used to drive the curriculum. One advantage to this model is that it allows the curriculum to remain autonomous, while still permitting integrated concepts to be incorporated to make connections between and among different disciplines.
Curriculum integration is not an end in and of itself, but a means to reach the educational goals established by the local, state, and national education systems. Nogay (1994) noted:

Integrated learning provides us a tool to establish better student learning in a relevance-based program ... Curriculum integration presents an opportunity to redefine the goals of education and reorganize instructional patterns ... Related knowledge and skills can provide intensified opportunities for student growth and increased exposure to the best that all teachers have to offer. (p. 17)

Curriculum integration is not easy to implement despite the enormous amount of suggestive literature in the education field. Curriculum integration takes time, effort, support, and financial commitment. In addition, teachers must change their belief systems in how they approach the curriculum; professional development must be obtained by teachers and schools interested in moving toward or implementing an integrated curriculum; and teachers have to better understand how to work with one another, to identify a few barriers (Loepp, 1999). Moreover, one should not relegate the thought that integration must happen all the time in order for the student to comprehend the “big picture.” There are times in an integrative format where a specific concept must come from a specific discipline. In fact, poor integrative attempts are no better than poor lessons used in traditional teaching and learning. “Educators should consider integration a potential tool that is feasible and desirable in some situations but not all” (Brophy & Alleman, 1991, p. 66). Curriculum integration, in the scope of the school, can help facilitate these requirements. “A sound curriculum would thus consider a succession of natural and vital units of experience, each centering around a real problem, each drawing
upon subject matter as needed, irrespective of boundary lines, and each eventually in
growth and capacity to live” (Smith, 1935, p. 270).

Theory and Practice

The theoretical framework behind curriculum integration stems from many resources, but is synthesized by examining the Integrated Mathematics, Science, and Technology (IMaST) Program developed at The Center for Mathematics, Science and Technology (CeMaST) on the campus of Illinois State University. In addition, the theories of constructivism, metacognitive knowledge, and brain-based learning also provided frames of reference used in this research study. The IMaST model stemmed from concepts partially found in theories of metacognition and brain-based learning, but primarily from Polya’s (1957) problem solving approach. Polya’s approach had four phases: (1) understand the problem; (2) devise a plan of action; (3) carry out the plan; and (4) examine the solution obtained (Meier, Hovde, & Meier, 1996). Problem solving is the chief instructional technique used in the IMaST Program, much like other technology, mathematics, and science education integration projects or programs. Uniqueness of this program stems from the facts that many theories, philosophies, and models were used to synthesize and frame IMaST’s theoretical model (see Figure 1, p. 20) into a working, action-based system of education (CeMaST, 1994; IMaST, 1997; Meier, Hovde, & Meier, 1996).
The premise of the model is based on an acronym called DAPIC. DAPIC stands for Define, Assess, Plan, Implement, and Communicate. In the Define part of the model, the students are to state the problem clearly. This statement serves to clarify and quantify what the students want and need to know. In the Assess part of the model, the goal is to learn as much as possible about the problem before developing a plan. At the Plan stage of the model, students develop alternative solutions to the problem, experimentation and testing of hypotheses are conducted, and finally a planned solution is developed. At the
Implement stage, the plan is implemented and data are gathered. In the Communicate stage, the results are analyzed, conclusions are reached, and results are shared (IMaST, 1997; Meier, Hovde, & Meier, 1996). This model is not a linear process. Students may start at different stages of the model at different times to solve the problem. This model, while unique to IMaST, is not unique to the field of technology education. For example, Hutchinson and Karsnitz (1994) and Todd, Todd, and McCrory (1996) also used design and problem solving models to establish their theoretical framework, thus providing students a model in which to successfully work through a series of guiding principles.

While not explicitly stated in IMaST literature, one cannot help but draw reference to metacognition and the role of the student. "Metacognitive knowledge as originated by Flavell (1976) is knowledge about one's own knowledge, skills, and abilities" (McGilly, 1994, p. 4). Examples of metacognitive skills include planning which study to use, monitoring activities during learning, and checking outcomes (McGilly, 1994, pp. 4-5). These skills are certainly used by students using the DAPIC model. Huitt (1997) described the abilities of active megacognition by listing questions students would answer while engaged in this type of learning:

1. What do I know about this subject, topic, issue? 2. Do I know what I need to know? 3. Do I know where I can go to get some information, knowledge? 4. How much time will I need to learn this? 5. What are some strategies and tactics that I can use to learn this? 6. Did I understand what I just heard, read, or saw? 7. How will I know if I am learning at an appropriate rate? 8. How can I spot an error if I make one? and 9. How should I revise my plan if it is not working to my expectations/satisfaction? (p. 1)
Further explanation by Hacker (1999) reveals

Metacognitive thoughts do not spring from a person’s immediate external reality; rather, their source is tied to the person’s own internal representations of that reality, which can include what one knows about that internal representation, how it works, and how one feels about it. (p. 2)

Constructivism, like metacognition, is not new to the education field. Constructivism is gaining more attention in the field of education, but more importantly to the idea of integrating curricula. In fact, Loepp (1999) when discussing the implications of implementing an integrated curriculum stated “teachers must shift their belief system from one that is primarily didactic in nature to one that has a foundation in constructivism” (p. 24). This theory of knowledge, an active mental process, is described as a process of adding new information to what is already known; a change in the learning environment (Brooks & Brooks, 1993; Driver & Bell, 1985; Johnson & Thomas, 1992). “A constructivist classroom determines the strength of school reform in merging learning and understanding beyond facts and rote memorization” (Constructivist Classrooms, 1993, p. 1). This type of knowledge is somewhat hard for a non-constructivist teacher to understand because so much flexibility must be granted to the students to “construct” their own knowledge of the content. Time and exploration of knowledge are chief in a constructivist approach and/or classroom.

An examination of the work Brooks and Brooks completed in 1993 on constructivist learning revealed strategies to help teachers become constructivist teachers and learners. Although not an easy task, constructivist learning offers a new approach to how students learn and the mental processes that are undertaken. Brooks and Brooks
(1993) provided teachers with examples and ways of communicating constructivism. In short, their work has taken some of the mystery out of changing the learning environment. In chapter 9 of their text, Brooks and Brooks offer the following strategies to teachers to become constructivists:

1. Constructivist teachers encourage and accept student autonomy and initiative;
2. Constructivist teachers use raw data and primary sources, along with manipulative, interactive, and physical materials;
3. When framing tasks, constructivist teachers use cognitive terminology such as ‘classify,’ ‘analyze,’ ‘predict,’ and ‘create’;
4. Constructivist teachers allow student responses to drive lessons, shift instructional strategies, and alter content;
5. Constructivist teachers inquire about students’ understanding of concepts before sharing their own understandings of those concepts;
6. Constructivist teachers encourage students to engage in dialogue, both with the teacher and with one another;
7. Constructivist teachers encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other;
8. Constructivist teachers seek elaboration of students’ initial responses;
9. Constructivist teachers engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion;
10. Constructivist teachers allow wait time after posing questions;
11. Constructivist teachers provide time for students to construct relationships and create metaphors;
12. Constructivist teachers nurture students’ natural curiosity through frequent use of the learning cycle model (discovery, concept introduction, and concept application). (Constructivist Classrooms, 1993, p. 2)
Another learning theory or approach to changing the traditional way teachers teach and how students learn that pertains in reference to integrating curricula is called brain-based learning. Similar to constructivism, brain-based learning is concerned with connecting the "whole" not the "parts" of learning. Stemming from neural psychology, brain-based learning deems as long as one's brain is not prohibited from processing, learning will occur. The core principles of brain-based learning are:

1. The brain is a parallel processor, meaning it can perform several activities at once, like tasting and smelling;
2. Learning engages the whole physiology;
3. The search for meaning is innate;
4. The search for meaning comes through patterning;
5. Emotions are critical to patterning;
6. The brain processes whole and parts simultaneously;
7. Learning involves both focused attention and peripheral perception;
8. Learning involves both conscious and unconscious processes;
9. We have two types of memory: spatial and rote;
10. We understand best when facts are embedded in natural, spatial memory;
11. Learning is enhanced by challenge and inhibited by threat; and

Synthesizing the elements and tenets of brain-based teaching and learning leads to the facts that concepts taught in the classroom must be set in a real-world context; the content and application of that content should be stimulating for students; the whole concept must be used, e.g., examining mathematics, science, and technology education, not isolated parts of these subjects; and learning is best accomplished by participation (Caine & Caine, 1991; 1995; 1997). One factor of interest, as pointed out by Beane (1996) in regard to curriculum integration is that of brain-based learning. Beane’s
synthesis of research provides us “the brain processes information through patterns and connections with an emphasis on coherence rather than fragmentation. Those who advocate integration from this research claim that the more knowledge is unified, the more it is ‘brain-compatible’ and, therefore, more accessible for learning” (pp. 8-9).

The argument for aligning brain-based learning theory to curriculum integration makes sense to some educators. Moving the learner from the traditional absorber of information to one who interacts dynamically with the information results in successful learning. Caine and Caine (1997) provide more information to support this claim:

Both memorization and integration are critical, and learning is best when information is embedded in rich, meaningful experiences…. Students and teachers become partners in the pursuit of understanding. Traditional schooling assumes that children have to take on board lots of ‘stuff,’ and then someday they will know how to apply it when they go to work or have a profession. Brain-based learning makes this leap to the real world right from the start. (p. 18)

There are, however, different views on brain-based education and the claims brought forth by many educators like the Caines presented in this literature review. Bruer (1999) argues that brain-based education does not stem from brain research, but rather cognitive psychology, behavioral sciences, and our understanding of the mind. “The danger with much of the brain-based education literature is that it becomes exceedingly difficult to separate the science from the speculation” (Bruer, 1999, p. 650). However, Bruer does state that “Effective brain-based educational strategies overlook neither parts nor wholes, but constantly attempt to provide opportunities in which students can make connections and integrate parts and wholes” (1999, p. 652). Furthermore, Bruer stated
“Brain science contributes no evidence, pro or con, for the brain-based strategies that the Caines espouse” (1999, p. 653).

The brain-based education literature represents a genre of writing, most often appearing in professional education publications, that provides a popular mix of fact, misinterpretation, and speculation. That can be intriguing, but it is not always informative. ‘In Search of …’ is no way to present history, and the brain-based education literature is not the way to present the science of learning.

(Bruer, 1999, p. 657)

Mathematics and Technology

Curriculum integration and learning theories are not the only educational constructs that have evolved over the years. Science, mathematics, and technology education are all under current reform. For example, a study conducted by Wentworth and Monroe (1996) concerning parent beliefs about technology and innovative mathematics instruction sheds some light in regard to barriers, beliefs, innovative mathematics instruction, and educational change. The purpose of their study was to interpret parents’ beliefs of education along with the use of computers in mathematics classrooms. The use of a computer does not mean that technology education was implemented or integrated, but rather a tool of technology was used for instructional purposes, i.e., instructional technology. The significance of this study to this current research project was not the use of the computer, but how parents perceive the role of the teacher and how the curriculum is implemented with technology in the classroom. The author’s findings and concluding comments bring to bear that change is difficult and parental beliefs about an innovative mathematics curriculum are difficult. “Teachers
need to be aware that many parents with an explicit view of education will not understand innovative mathematics instruction and technology in the classroom" (p. 132).

Technological advances have all but eliminated the need for paper-and-pencil computational skill. As a result, a major thrust of the reform movement has been the effort to replace the current obsolete, mathematics-as-computation curriculum with a mathematics curriculum that genuinely embraces conceptual understanding, reasoning, and problem solving as the fundamental goals of instruction. (Battista, 1994, p. 463)

The National Research Council (NRC) (1989) in one of its most often cited research publications in education today described the rationale and need for reform of mathematics in the United States. “We have inherited a mathematics curriculum conforming to the past, blind to the future, and bound by a tradition of minimum expectations” (p. 1). In a section titled “Mathematics for Tomorrow”, the NRC cited several factors for the call for mathematics reform; a call that can be construed as another rationale for curriculum integration. These factors include the growth of technology, increased applications, impact of computers, and expansion of mathematics (p. 4). An examination of mathematics literature revealed the reform movements that have been attempted over the past 50 years. During the 1950s and 1960s a reform movement emerged called “new math.” This reform, as all mathematics teachers know failed, the reasons were many. For instance, the idea was never embraced across the field, which is not a surprise because no reform movement is ever accepted by all parties. However, the reasons for failure of new math were much deeper. Students were never the subject of the reform movement and learning theories that helped students were not addressed. In
addition, teachers and their knowledge base were not part of the formula. "Back to Basics" was another reform movement of the mathematics field. This movement emphasized memorization and paper-pencil calculations. Again, this movement failed (Lacampagne, 1993).

In 1986 and eventually the rest of the decade and into the early 1990s, the National Council of Teachers of Mathematics (NCTM) addressed the reform of mathematics. The NCTM (1991), after examining past practice, identified and recommended five major shifts to reform:

1. toward classrooms as mathematical communities – away from classrooms as simply a collection of individuals;
2. toward logic and mathematical evidence as verification – away from the teacher as the authority for right answers;
3. toward mathematical reasoning – away from merely memorizing procedures;
4. toward conjecturing, inventing, and problem solving – away from an emphasis on mechanistic answer-finding;
5. toward connecting mathematics, its ideas, and its applications – away from treating mathematics as a body of isolated concepts and procedures. (1991, p. 3)

From the technology education side of these reform movements, reforms four and five are significant. From a theoretical basis, the entire recommendations moved the field of mathematics, in theory, to that of a constructivist approach to teaching and learning. Reform statements four and five emphasize problem solving, connections, and application: a base for technological literacy. "Teachers who listen to students, and who plan instruction based on what they learn from listening, transform student learning....Students who construct their own mathematical understanding transform their
mathematical potential” (Lacampagne, 1993, pp. 4-5). Hiebert, Carpenter, Fennema, Fuson, Human, Murray, Olivier, and Wearne (1996) on the research of problematizing mathematics curriculum instruction provided the following statement “Allowing the subject [mathematics] to be problematic means allowing students to wonder why things are, to inquire, to search for solutions, and to resolve incongruities. It means that both curriculum and instruction should begin with problems, dilemmas, and questions for students” (p. 12). Problematizing mathematics can also be construed as another call for reform that supports constructivism and brain-based learning. In the same year as the NCTM created their standards document, Bitter and Frederick (1989) were examining ways of reforming mathematics with the inclusion of technology

Rapidly changing technology affects not only how we do things in the school, but also what skills are taught. This is particularly true in mathematics, where new technology and new techniques are increasing the importance of mathematical knowledge. (p. 22)

Examining the NCTM standards of 1989, one can readily attest to the reform movements presented. For example, starting at grades K-4, problem solving is a standard in which the mathematics teachers should instill in their students. This problem solving approach is not a word problem, but more along the lines of a mathematical problem that is provoking and needs to examined, clarified, and applied to another context. Moreover, at the K-4 level, the standards suggest a constructivist approach to teaching and learning by stating, “Young children are active individuals who construct, modify, and integrate ideas by interacting with the physical world, materials, and other children. Given these facts, it is clear that the learning of mathematics must be an active process” (NCTM,
Examining the NCTM standards for grades 5-8, one can also see the addition of problem solving, but more importantly a section of the standards on connections. These connections, once again, provide a rationale for curriculum integration. These connections as highlighted by the NCTM are in place to connect mathematics with other subject areas, to provide real world contexts, and to apply mathematics. The standards for the 9-12 grade levels are rigorous. The NCTM suggests that a minimum of three years of mathematics are needed in order to satisfy these standards. Of all the grade level standards, the 9-12 grade standards show the most reform. These reformed standards can be summed up with the following statement:

The 9-12 standards call for a shift in emphasis from a curriculum dominated by memorization of isolated facts and procedures and by proficiency with paper-and-pencil skills to one that emphasizes conceptual understanding, multiple representations and connections, mathematical modeling, and mathematical problem solving. (NCTM, 1989, p. 125)

Science and Mathematics

Following the reform movements of mathematics, science educators created standards documents and called for a major overhaul in the way science education is structured and taught (AAAS: Project 2061, 1993; NRC: National Science Education Standards, 1996; Rutherford & Ahlgren: Science for all Americans, 1990). One of these reform movements centered around the issue of integrating mathematics and science education. Berlin (1990) noted a lack of literature at the high school level related to the integration of science and mathematics. However, since Berlin’s work in 1990, several articles have been written and studies conducted on the integration of science and
technology (Clewell, Anderson, & Thorpe, 1992; Haigh & Rehfeld, 1995; Pleacher, 1998; Wasley, Donmoyer, & Maxwell, 1995), but a lack of professional literature still remains dealing with the integration of these disciplines, along with technology education at the high school level. The key thought of integrating science and mathematics, as described by Davison, Miller, and Metheny (1995):

is to develop relevancy and applicability of the discipline to the existing student experiences. Students must see mathematics, as well as science, as relevant components of their world. In other words, mathematics should no longer be seen as a discipline studied and applied for mathematics sake, but rather, because it will help make sense out of some part of our world (p. 226).

Mathematics, when integrated with science, provides the opportunity for students to apply the discipline to real situations, situations that are relevant to the student’s world and presented from the student’s own perspective. (Davison et al., 1995, pp. 226-227)

After the reform movement and publication of the various standards documents regarding science education, a group of teachers gathered and created four recommendations:

(1) Science and math curriculum content should be reduced so that students have the time to learn concepts and skills thoroughly. (2) Students should be able to apply skills, concepts, and research methods to fresh circumstances as a way of demonstrating their thorough understanding. (3) Disciplines should, in some way, be integrated in order to help students better understand the relevance of academic knowledge for solving world problems. (4) Students should be able to formulate
problems, discern potential solutions, conduct experiments, and draw conclusions.

(Wasley, Donmoyer, & Maxwell, 1995, p. 52)

Science and Technology

In addition to the reform movements integrating science and mathematics, the integration of science and technology education has also gained momentum. Bybee (1998) provides justification for integration with the following statement:

Technology's important links to science should be a part of science classes.

Technology has its own distinct knowledge and abilities that students need to understand and develop, and there are opportunities for teachers to address technology within the context of science classes. (p. 38)

The momentum gained in the integration of science and technology has not come easily. Much resistance by both science and technology educators exists. This resistance comes in the form of many reasons, but chiefly is centered on arguments about the evolution of science and technology. Educators take different positions on the roles of science and technology. For example, which discipline came first, science can flourish without technology; technology can flourish without science.

Perhaps it is mostly because traditional industrial arts [technology education] and science programs have existed for so long that many inside the schools as well as in the general public think that these offerings should continue uninterrupted, essentially unchanged and unchanging. (Lux, 1984, p. 16)

What has been missing from these arguments is the student. Moreover, the fact that technology education is not required of all students in the United States makes technology education seem like less of an importance. If one were to read the science
standards, one would easily concur that the role that science and technology place in our world are insurmountable; one cannot live without the other and they should be integrated. “The fact that technology is associated with those who do manual work, whereas the education system is largely controlled by those who do not, has tended to give technology a lower status in education than science” (Carelse, 1988, p. 101).

What can be said is that if we look more deeply into the two areas of science education and technology education we discover that each is but a facet of the other, and that their separation has had undesirable effects, not simply on the quality of education as a whole, but also on the extent of opportunities available for the development of every child. (Carelse, 1988, p. 102)

The purpose of science is to develop an understanding of the natural world. Technology education is focused on designing and altering the material world for human purposes. This includes the design of both the physical and the social world. The inclusion of design and technology in Science Standards is a clear indication that the science education community recognizes and values the unique and important contribution of technology education. (Custer, 1996, p. 8)

**Technology Education**

Just as mathematics and science education reformed their disciplines, technology education reformed its position on teaching and learning. In 1985, [then industrial arts] the field changed its position to one of technology, although the call for technology was much earlier (DeVore, 1980; Olson, 1963; Warner, 1947). Creating a rationale for technology education in today’s schools, Bensen (1995) noted:
Technology is everywhere and it is an integral part of how and where people live, work, recreate, and socialize. Without technology, humans are extremely limited in what they can accomplish, but with it, humans are able to exert virtually unlimited power and energy in reaching their full potential. (p. 1)

Merrill (1997) defined technology education as:

A hands-on, minds-on general education for all students. Technology education engages learners in developing literacy in the study of technology and society, with the use of problem solving and critical thinking skills; implementing a broad spectrum of action-based delivery systems, which readily facilitate integration among other learning disciplines across the curriculum; fostering safety, design, manipulative skills and techniques, awareness of technological careers, and providing a vehicle for understanding historical and future technological developments in the areas of communication, manufacturing, construction, transportation, and bio-related technologies. (pp. 6-7)

The end result or goal of students having and taking part in technology education is technological literacy. In the 40th yearbook of the Council on Technology Teacher Education (1991), technological literacy is defined by Dyrenfurth as:

A concept used to characterize the extent to which an individual understands, and is capable of using technology. Technological literacy is a characteristic that can be manifested along a continuum ranging from non-discernible to exceptionally proficient. As such, it necessarily involves an array of competencies, each best thought of as a vector, that includes: Basic functioning skills, and critical thinking, construction work habits, a set of generalized procedures for working
Examining the draft standards for technology education (the Standards for Technological Literacy: Content for the Study of Technology were not released until April 2000, so the researcher has called the standards mentioned in A Rationale and Structure of Technology "draft standards") presented in A Rationale and Structure for Technology revealed three universals: Processes, Knowledge, and Contexts:

Processes: Human activities to create, invent, design, transform, produce, control, maintain, and use products or systems.

Knowledge: How technological content is developed and applied.

Contexts: The larger areas where technology is developed, applied, and studied, which are categorized by informational, physical, or biological/chemical systems.

(Technology for All Americans, 1997)

These draft standards were written from a perspective that they would be timeless, even in an era of uncertainties and accelerated change (TfAAP, 1997).

In A Rationale and Structure for Technology, the Technology for All Americans Project (TfAAP) described technology education to be "an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities" (TfAAP, 1996, p. 13). This rationale and structure document served the technology education community (until the official standards were published and released in April 2000) as the guiding force and mission for U.S. schools. Different from the mathematics and science education standards, the technology education draft standards in A Rationale and Structure for Technology did not
have a benchmark for students at specific grade levels. Rather they categorized the K-12 educational experience as (1) elementary school years; (2) middle school years; and (3) high school years and beyond.

A description of these educational categories by which the rationale and structure document were organized describes the elementary school years experience in technology education to active learning where students can be engaged in the design of products, systems, and environments, thus enabling them to relate this knowledge to related subjects. At the middle school years, students gain further understanding of the nature and evolution of technology by applying principles of engineering, architecture, and industrial design. At the high school level and beyond, students enhance their understanding of technology by taking sequential courses in technology, e.g., communications, manufacturing (TfAAP, 1996).

As a result of taking technology education, the Technology for All Americans Project created five goals students need to possess:

(1) Evaluate technology’s capabilities, uses, and consequences on individuals, society, and the environment; (2) Employ the resources of technology to analyze the behavior of technological systems; (3) Apply design concepts to solve problems and extend human capability; (4) Apply scientific principles, engineering concepts, and technological systems in the solution of everyday problems; and (5) Develop personal interests and abilities related to careers in technology. (TfAAP, 1996, p. 40)
Previously mentioned above and in Chapter 1, the official standards for technology education were released in April 2000. These standards encompass many different facets of teaching and learning, but do not constitute a curriculum. Rather, the Content for the Study of Technology describes what should be taught in grades K-12. The content standards were designed around benchmarked grade levels of K-2, 3-5, 6-8, and 9-12. The content standards were organized around five major categories: (1) The Nature of Technology; (2) Technology and Society; (3) Design; (4) Abilities for a Technological World; and (5) The Designed World. In addition to the benchmarked grade levels, twenty standards were written to help guide curriculum developers and teachers in achieving technological literacy for all students (International Technology Education Association, 2000).

Similar to the mathematics and science education standards, the Content for the Study of Technology has a focus on integrating knowledge or drawing upon other disciplines to allow students and teachers to gain a real-world perspective. The standards pertaining to this research study were: (1) The relationships among technologies and the connections between technology and other fields; (2) The cultural, social, economic, and political effects of technology; (3) The effects of technology on the environment; (4) The influence of technology on history; (5) Assess the impact of products and systems; (6) Energy and power technologies; (7) Transportation technologies; and (8) Manufacturing technologies.
Integration can be thought of as a puzzle with intricate shapes. Each separate shape fits into another. If one piece of the puzzle is missing, the entire whole is affected. Simply, integration is bringing the parts together to represent the whole, and in this case, the whole is technology, mathematics, and science education. TMaSe build upon one another. Technology, although crude at the time, was implemented before formal scientific theories and mathematical equations were developed (Fensham & Gardner, 1994). However, in today's technological society, the areas cannot stand alone. Through recent studies (Brusic, 1991 & Childress, 1996), students in an integrated program of technology, mathematics, and science education have an increased curiosity regarding the connections between and among technology, mathematics, and science education. However, the hypothesis of "improved student learning," has not been accepted. These conclusions, however, do not mean that all is lost or that an integrated approach to technology, mathematics, and science education is not a valid curricular option. In fact, these conclusions mean that further research is needed in the TMaSe area to probe the curriculum, methodological, philosophical, theoretical, and implementation underpinnings of this educational approach.

One of the major reasons for investigating curriculum integration is that school subjects have been traditionally taught and constructed in isolation of other school subjects and disciplines within the educational cycle. Students must be taught to see the whole, the relationships (Kliebard, 1985). Through curriculum integration "students will understand the connections between apparently disparate bodies of knowledge and will better appreciate the inherent complexity of the world we live in" (Martin-Kniep, Feige, 38
& Soodak, 1995, p. 227). Current research in the field of technology education by McCade and Weymer (1996) provided a simple synthesis of the integration of technology, mathematics, and science education:

There are certain "thinking and doing" skills associated with science, mathematics, and technology that young people need to develop during their school years. These are essential skills for formal and informal learning and for a lifetime of participation in society as a whole. Taken together skills can be thought of as habits of the mind, because they all relate to a person's outlook on knowledge and learning and ways of thinking and acting. (p. 42)

Drake (1997) stated that "In the United States curriculum integration has been slow to take hold because few teachers can agree on what it means, let alone work out turf issues or let go of traditional methods" (p. 24). With the daunting task of creating an integrated curriculum for technology, mathematics, and science education at the secondary level, one must heavily rely on past practices, theories, and knowledge to gauge the appropriate means of tackling the problem of curricular integration and creating a scenario for immediate implementation in today's schools.

From the point of view of a serious educator, whatever the historical period or the particular setting, the question of what to teach involves a selection from a vast array of knowledge and belief within a culture. Since it is impossible to teach everything, that selection from the culture reflects in part some sense of what is most worthwhile in that culture seen in relation to the kind of institution the school is and what it can reasonably accomplish. (Kliebard, 1985, p. 31)
While these are broad characteristics of an integrative approach, they are the foundation in which a curricular movement like TMaSe can be implemented. Ortega and Ortega (1995) stated “Integrated technology education encourages and enables students to be curious and creative and develop their problem solving skills” (p. 12). Further research by Wicklein and Schell (1995) pointed to “The integrative or multidisciplinary curricular approach related to technology education seeks to help students learn and appreciate the relevancy of how school subjects are tied together and how each subject builds on the other” (p. 59).

Summary

There are varying positions on integrated teaching and learning and several models that could be implemented in today’s schools. Moreover, varying positions on the theoretical, philosophical, and methodological frameworks used to develop and implement this type of curriculum. The mathematics and science communities have recognized a need to become more acclimated toward real-world applications, which is evident in each organization’s teaching and learning standards. Technology education has also gone through its own transformation of what should be taught in schools, how this curriculum should be taught, and what each student should be able to know and do.
CHAPTER 3

DESIGN-METHODOLOGY-RESEARCH

Chapter three presents the design and methodology for this research study. The problem or reason for the study is paraphrased, and the research design, methodology, population, treatment and comparison group's curriculum materials, instrumentation, data collection and analysis, and how variables were controlled are presented and discussed.

As stated in Chapter One, the integration of technology, mathematics, and science education at the secondary level is a growing concern. Measuring the educational worth of an integrated approach to teaching and learning; how to overcome implementation barriers at the secondary level; and assessing student learning using integrated approaches were the problems the researcher identified for this study. The approach taken by the researcher in attempt to deal with these problems and test existing theories of technology, mathematics, and science education field was one of scientific experimentation completed in the public arena in a small suburban high school located in the United States; an opportunity to test the stated research hypotheses.

In order to test the hypotheses for this research study, the researcher utilized an experimental design. Ary, Jacobs, and Razavieh (1996) stated:
An experiment is a scientific investigation in which the researcher manipulates one or more independent variables, controls any other relevant variables, and observes the effect of the manipulations on the dependent variable(s) . . . it is the research method that provides the most convincing evidence of the effect that one variable has on another. (Ary, Jacobs, & Razavieh, 1996, p. 306)

The purpose of experimental research is to test cause and effect relationships among variables. The researcher manipulates one variable to measure the effect of this manipulation upon the dependent variable. In order to have a true experiment, three things must be evident: (1) there must be at least two groups; (2) the researcher must manipulate the independent variable; and (3) experimental units must be randomly assigned to groups. A quasi-experimental design, however, lacks at least one of the three items listed above. For this study, the researcher had two different groups; the researcher manipulated the independent variable(s); but could not randomly sample the subjects. The researcher randomly assigned intact technology education classes.

Research Design

A modified quasi-experimental nonequivalent control group design was utilized for this research study. The modification of the design stemmed from the fact that the researcher used comparison groups rather than “true” control groups.

Campbell and Stanley (1963) stated that this design is “one of the most widespread experimental designs in educational research” (p. 47). The three experimental and three comparison groups used in this research study were second semester intact high school
technology education classes comprised of 9-12 grade students currently enrolled. The experimental groups were those subjects that had the courses commercial design, industrial education orientation, and pre-engineering graphics on the “A” day of the week. While the comparison groups were those subjects that had the courses building trades, CAD, and wood production on the “B” day of the week. The two groups “constitute naturally assembled collectives such as classrooms, as similar as availability permits but yet not so similar that one can dispense with the pretest” (Campbell & Stanley. 1963, p. 47).

Methodology

For reasons of internal validity, more specifically implementation or implementer threat, the same technology education teacher instructed the experimental and comparison groups. An implementer effect can occur when different individuals are assigned to implement different methods, and these individuals differ in ways related to the outcome (Ary, Jacobs, & Razavieh, 1996). Both groups were issued a 100-question (63 forced-choice questions and 37 open-ended questions) pretest on the first day of the research study. For the next two weeks (six block-scheduled periods or 426 minutes) of the research study, the experimental groups received the treatment (six different lessons depicting an integrated, hands-on, minds-on curricula via the Pedal 4 Power Energy Education Bicycle). The comparison groups also received the identical six lessons given to the treatment groups, but did not have the integrated teaching and learning approach or the hands-on experience with the energy education bicycle. Instead, the comparison groups received activities to reinforce the curriculum content in the form of workbook exercises.
Upon completion of the curricula, both groups were issued a 45-question (of the original 100-question pretest) posttest. Twenty-seven forced-choice questions and 18 open-ended questions made up the posttest. Two weeks after the posttest, each group was given a second posttest. This posttest instrument was made up of 45-questions (of the original 100-question pretest). The questions on the second posttest instrument were different from that of the first posttest. Two weeks after the conclusion of second posttest, the groups were tested again for retention. This instrument was 33 questions and based from the original 100-question pretest. The researcher randomly picked 23 forced-choice questions and 10 open-ended questions.

The researcher, to obtain reliability of the instruments, used Cronbach’s coefficient alpha as the index of reliability through SPSS® Version 10.0.5 for Windows®. The posttest1 reliability coefficient for the 27 forced-choice questions was $r=.70$, and the 18 open-ended questions was $r=.87$. The posttest2 reliability coefficient for the 27 forced-choice questions was $r=.69$, and the 18 open-ended questions was $r=.87$. The posttest3 reliability coefficient for the 23 forced-choice questions was $r=.68$, and the 10 open-ended questions was $r=.80$. The reason the researcher used fewer questions on the posttests than what appeared on the pretest was to try to alleviate the internal validity threat of testing. Moreover, since the reliability of all four instruments were similar, the researcher felt confident that the instruments would provide the appropriate statistical data while still maintaining the validity and integrity of the study.
Population and Sample

The number of research subjects that were part of this research study was 71. The following information describes how the researcher ended with this number of subjects. The total population (student enrollment) for the high school in the United States used for this study was 225. The high school was purposefully chosen for this study because of implementation ease and geographical location. The population of subjects (N=90 high school students) for this study was also purposefully chosen. Of the total N=90, 49 subjects were assigned to the experimental group based upon their school day and academic schedules. Of these 49 subjects, one chose not to participate, one was removed because of attendance problems, and eight were removed because they were enrolled in more than one technology education class (these subjects were enrolled in both the experimental classes and the comparison group classes, i.e., both "A" day and "B" day). The remaining number of subjects that were experimentally accessible for the experimental groups was 39. Of these 39 subjects in the experimental groups, there were 27 boys and 12 girls. The researcher randomly assigned the subjects to the experimental and comparison groups in order to equalize the groups. The basis on which the researcher made this decision was strictly for the number of subjects representing both groups.

Of the original N=90 subjects, 41 were assigned to the comparison groups. Of these 41 subjects, three were removed for attendance problems and six were removed because they either participated in the experimental groups or in a comparison group that met earlier or later in the school day or on a different day during the school week. The remaining subjects that were experimentally accessible in the comparison groups was 32.
Of these 32 subjects, 24 were boys and 8 were girls. Thus, after starting with an N=90 and removing the subjects from both groups for the various reasons stated above, the final population of research subjects was N=71.

The significance criterion (alpha level) for this research study was set at .05. These classes were statistically equivalent: three in the experimental group and three in the comparison group.

When subjects have been randomly assigned to groups, the groups can be considered statistically equivalent. Statistically equivalent does not mean that the groups are absolutely equal, but it does mean that any difference between the groups is a function of chance alone and not a function of experimenter bias, subjects' choices, or any other factor. (Ary, Jacobs, & Razaviech, 1996, p. 318)

Since the experimental design for this research study utilized intact classes, the target and accessible populations were synonymous. This research study, content, and activities were implemented in place of the curriculum established by the technology education teacher to be taught during the normal semester curriculum. Since this research study was based on technology education, the curriculum the students would have normally received was not hindered, but enriched. Moreover, students were not subjected to curriculum that was unfamiliar or unrelated to the goals of technology education. No individual student was randomly selected for this study; intact classes were randomly assigned to the experimental and comparison groups based on the academic schedule (accessibility) of the school and students.
Treatment and Comparison Groups Curriculum

The treatment groups were involved in integrated technology, mathematics, and science education using the constructivist approach to teaching and learning. The teacher willingly implemented the curricula in the form of a "cookbook" list of educational instructions to follow which helped insure that the teacher did not deviate from the prescribed teaching methodology being used for this research study. In addition, the instructional material was made available to the teacher in the form of student handouts and overhead transparencies. Throughout the curriculum activities, the students were asked to construct their own meanings of concepts and constructs before and after content was delivered. At the same time, the teacher was reinforcing the integration of technology, mathematics, and science education through the lessons. As part of the instructional lessons, students in both the experimental and comparison groups completed mathematically related questions that pertained to the lesson topic. However, the comparison groups were not presented with the integrated approach or the constructivist method of teaching. Moreover, the concepts, facts, and information for both groups were identical.

Using the concepts of integrated technology, mathematics, and science education, curricula and activities that reinforced and were centered around energy and power technology via the use of the Pedal 4 Power Energy Education Bicycle were created and implemented for the treatment groups. Six different lessons and activities were created and implemented for both groups. These lessons specifically focused on energy, power, energy efficiency, and mechanical advantage as related to the technology, mathematics, and science education national curriculum standards. The subjects in both groups had
instructional (content) lessons in addition to activities. The treatment groups used the energy education bicycle to reinforce the instructional content presented, while the comparison groups had workbook type of activities to reinforce the content they were presented. The curriculum and activities used were based on ninth grade technology, mathematics, and science education curriculum and were instructionally time equivalent. The researcher assumed that subjects participating in this research study completed at least one ninth grade class in technology, mathematics, and science education (see Appendix A for curriculum).

**Instrumentation**

At the time of this study, no standardized assessment tool or instrument for assessing the integration of technology, mathematics, and science education existed. Pretest and posttest instruments were created for use by both groups of subjects. These instruments focused on energy and power technology and how they relate to technology, mathematics, and science education (see Appendix B for instrument).

The instruments needed for this research study were field-tested, pilot-tested, validated, and deemed reliable. Ary, Jacobs, and Razavieh (1996) defined validity as "referring to the extent to which an instrument measures what it is intended to measure" and reliability as "the extent to which a measuring device is consistent in measuring whatever it measures" (p. 262). In order to achieve validity of the research instruments and ultimately the research study, the researcher relied on and used content-related evidence. Content-related evidence, as described by Ary, Jacobs, and Razavieh (1996) "shows the extent to which the sample of items on a test is representative of some defined universe, or domain of content" (p. 263). This evidence was gathered by the researcher.
in two forms: (1) a panel of experts from inside and outside of The Ohio State University representing knowledge on the integration of technology, mathematics, and science education. These experts examined the content of both the curriculum used in the research study and the instruments needed to measure the dependent variable(s). (2) Secondary school teachers in technology, mathematics, or science education were selected to examine the curriculum and instruments. Both sets of panel of experts were given the curriculum and instruments along with a supplementary checklist asking them to carefully and critically examine the content to determine the relationship between the test and the defined universe.

At the conclusion of the content validity evaluation and field-testing, the researcher made necessary changes and sent the curriculum and instruments back to the panels of experts. Once the validity had been established to the best ability of the researcher, a pilot test was implemented at a high school, separate from the actual research site. Two different technology education classes were used in the pilot testing, which provided a similar sample of subjects. These pilot test subjects were similar to the actual research subjects on demographic data such as gender, age, year in school, and technology, mathematics, and science education course history and enrollment. These pilot test subjects did not participate in the research study, but possessed similar characteristics to those subjects that actually took part in this research study. The researcher found no discrepancies in the sample subjects and the actual research subjects used for this research protocol. The pilot test consisted of the pretest used in the actual research study and every instrument thereafter. The researcher, to obtain reliability of the instruments, used Cronbach’s coefficient alpha as the index of reliability through SPSS®.
Version 10.0.5 for Windows®. This pilot test yielded the researcher reliability data on the procedures, curriculum, and instruments purported to be used. The reliability coefficient for the 67 forced-choice questions was $r = 0.84$, and the 33 open-ended questions yielded a reliability of $r = 0.93$. Fraenkel and Wallen (1993), when discussing reliability of instruments, reported that “reliability should be at least .70 and preferably higher” (p. 149).

**Data Collection**

The collection of data for this research study was accomplished in several ways: (1) All instruments the subjects used were coded with a random number. Only the researcher and cooperating teacher knew which code number represented an individual student. The code numbers were used to insure every subject enrolled in the treatment and comparison groups completed all instruments. (2) The pretest was administered to all groups on the first day of the research study. (3) All subjects, to the best of the researcher’s and cooperating teacher’s ability were present for each lesson. (4) The posttest was administered at the conclusion of the research study. (5) Two weeks after the conclusion of the initial research study, all groups involved were issued another posttest. (6) Two weeks after the second posttest, all groups involved were issued the final posttest.

**Data Analysis**

Data was gathered, selected, and processed using the following statistical processes: measures of central tendency, frequency and percentage, computed t-value, and measures of variability. These statistical processes were computed using SPSS® Version 10.05 for Windows® software.
The following variables were identified for this research study and are discussed by hypotheses:

Hypothesis One: High school students who are engaged in integrated technology, mathematics, and science education curricula taught by a technology education teacher, would have an increased cognitive learning effect as compared to high school students not receiving an integrated curricula in technology, mathematics, and science education as measured by the mean score on the integrated energy and power technology posttest instrument.

For research hypothesis one, there were two levels of the independent variable: integrated technology, mathematics, and science education using the constructivist approach to teaching and learning and the non-integrated/constructivist approach to teaching and learning. The dependent or outcome variable for research hypothesis one was learning effect, that is, the change in cognitive knowledge as measured by an increase or decrease on the posttest technology, mathematics, and science education instrument. Learning effect and corresponding scores on this variable were treated as interval data.

Hypothesis Two: Subjects participating in the integrated curricula approach would identify more terms, phrases, and examples of how technology, mathematics, and science are connected in real-world constructs, than those subjects not receiving an integrated curricula approach, as measured by the frequency of terms, phrases, and examples on the posttest instrument.

The independent variable for research hypothesis two had two levels: integrated technology, mathematics, and science education using the constructivist approach to
teaching and learning and the non-integrated/constructivist approach to teaching and learning. The dependent variable for research hypothesis two was students’ perceptions of terms, phrases, and constructs that represent technology, mathematics, and science. These terms/phrases were treated and measured as interval data.

Hypothesis Three: Subjects participating in the integrated curricula approach would have an increase in content retention two and four weeks after the study has been completed, as measured by the mean score on the posttest retention instrument, than those students not receiving an integrated curricula approach.

The independent variable for research hypothesis three had two levels: integrated technology, mathematics, and science education using the constructivist approach to teaching and learning and the non-integrated/constructivist approach to teaching and learning. The outcome variable for research hypothesis three was retention after two and four weeks. Retention was measured as the mean score on the posttest instrument and treated as interval data.

Control of Variables

There were several variables that had to be controlled in order for this research study to be deemed a success: the teacher implementing the curricula, the curriculum and activities constructed by the researcher, and the research instruments used to gather the needed data. The curricula was appropriately field-and pilot-tested to insure reliable and valid results. The research instruments, much like the curricula, were field-and pilot-tested to insure reliable and valid measurements. The pilot-test site was similar to the research site, wherein there was one technology education teacher, intact classes were used, students came from different, but similar economic and social backgrounds, and
different cognitive levels were present among students. Data gathered from these preliminary tests yielded the researcher the needed data to deem whether the instruments were measuring what they were supposed to be measuring, whether the instruments measure what they were supposed to be measuring on a consistent basis, and how easily the instruments could have been read and used by teachers and students alike.
CHAPTER 4

FINDINGS-PRESENTATION OF RESULTS

Chapter four includes a paraphrased statement of the problem and purpose for this study. In addition, the objectives, research and statistical hypotheses, and the findings of this research study in the form of statistical data are presented. Various tables are presented in this chapter along with brief explanations of the data. The purpose of this study was to test curriculum integration in technology, mathematics, and science education. The research study was completed in the public arena at the secondary level in a small suburban high school located in the United States. As stated in Chapter One, the integration of technology, mathematics, and science education at the secondary level is a growing concern. Past and current research has not produced a conclusion how to measure the educational worth of integrated approaches to teaching and learning; how to overcome implementation barriers at the secondary level; nor has an assessment tool been developed to measure student learning using an integrated approach. These problems formed the objectives from which this study was predicated.
The objectives of this study were to:

1. Provide the background, analysis, and evaluation of the methodological, theoretical, and philosophical underpinnings of technology, mathematics, and science education curriculum integration at the high school level;

2. Design and construct hands-on, minds-on activities that focus on and address the mapped national standards in each of three prescribed disciplines;

3. Address selected content and knowledge with an application of an integrated approach to teaching and learning technology, mathematics, and science education; and

4. Assess how students view the relationships between and among technology, mathematics, and science education.

The major questions of this research study were:

1. Does the teaching of high school level integrated technology, mathematics, and science education content and activities, in conjunction with mapped national standards in each of the three subject areas and taught by technology education teachers in technology education laboratories, have an immediate cognitive learning effect and do students have long-term learning retention on technological, mathematical, and scientific problems?

2. How do students view the relationship between mathematical constructs and technology education?

3. How do students view the relationship between scientific constructs and technology education?
4. How do students view the relationship between technological constructs and mathematics and science education?

5. Is retention of content improved over a long-term period through an integrated teaching and learning approach?

Findings

The following is a summary of the findings from the data collected in response to the hypotheses used for this research study.

Table 1 displays the descriptive statistics collected in response to hypothesis one for the experimental and comparison groups on the pretest and posttest1 research instruments. The research hypothesis (H_a) and the statistical hypothesis (H_0) were:

1.1 (H_a: μ₁ > μ₂) High school students who are engaged in integrated technology, mathematics, and science education curricula taught by a technology education teacher, will have an increased cognitive learning effect as compared to high school students not receiving an integrated curricula in technology, mathematics, and science education as measured by the mean score on the integrated energy and power technology posttest instrument.

1.2 (H_0: μ₁ = μ₂) There will be no difference in mean scores between the experimental and comparison groups on the integrated energy and power technology posttest instrument. 
<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Ms</th>
<th>Mdn</th>
<th>Mode</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
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<td>62</td>
<td>62</td>
<td>12.76</td>
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<td>83</td>
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<td>Pretest Comparison</td>
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<td>65</td>
<td>59, 66</td>
<td>13.23</td>
<td>34</td>
<td>84</td>
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<td>74</td>
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<td>37</td>
<td>100</td>
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<td>Posttest 1 Comparison</td>
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<td>76</td>
<td>78</td>
<td>14.55</td>
<td>41</td>
<td>96</td>
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</tbody>
</table>

Table 1: Group Statistics: Pre and Posttest 1

Note. The mean score (Ms) was calculated based on a 100-point scale with the higher scores indicating a higher number of items answered correctly.

Table 2 displays the statistical data required for testing hypothesis one. An independent samples t-test for both groups on the pretest and posttest 1 was performed. The computed t-value was calculated by using SPSS® Version 10.0.5 for Windows®.

<table>
<thead>
<tr>
<th>Instrument/Group</th>
<th>N</th>
<th>Ms</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig. (1-tailed)</th>
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</thead>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exp</td>
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<td>12.76</td>
<td>-.459</td>
<td>69</td>
<td>.32</td>
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<tr>
<td>Com</td>
<td>32</td>
<td>62.34</td>
<td>13.23</td>
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<tr>
<td>Posttest 1</td>
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</tr>
<tr>
<td>Exp</td>
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<td>71.69</td>
<td>15.40</td>
<td>-.504</td>
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<td>Com</td>
<td>32</td>
<td>73.50</td>
<td>14.55</td>
<td></td>
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</tbody>
</table>

Table 2: Independent Samples T-Test: Pre and Posttest 1

No statistically significant differences were found on the pretest and posttest 1 between the treatment (experimental) and comparison groups at the .05 α level. Therefore,
statistical hypothesis one was not rejected. In other words, the treatment did not have a statistically significant effect on student learning immediately following implementation.

Table 3 presents a summary of the findings from the data collected in response to hypothesis two. Table 3 displays the descriptive statistics for the experimental and comparison groups on the pretest, posttest1, posttest2, and posttest3. The pretest consisted of 37 terms and/or phrases that represented technology, science, and mathematics. Posttest1 consisted of 18 (of the original 37) terms and/or phrases that represented technology, science, and mathematics. Posttest2 also consisted of 18 (of the original 37) terms and/or phrases that represented technology, science, and mathematics. Posttest3 consisted of 10 (of the original 37) terms and/or phrases that represented technology, science, and mathematics. Of these open-ended terms and/or phrases, power, work, amperage, hydraulic, and thermal energy appeared on all three posttests. Therefore, these five items were the only terms and/or phrases statistically reported.

When responding to these open-ended terms and/or phrases, the research subjects were asked to choose technology, science, or mathematics independent from one another, a combination of any two, or chose all three. The instrument was coded so that a “one” represented students choosing technology, science, or mathematics, indicating a non-integrated orientation. A “two” meant choosing a combination of two terms, i.e., technology and science, technology and mathematics, or mathematics and science, indicating a semi-integrated orientation. A “three” meant students chose all three terms (technology, science, and mathematics), indicating a completely integrated orientation.

Table 3 displays the descriptive statistics for subjects who chose “three” or “all.” Examination of table 3 reveals that the valid percent of scores for these five terms and/or
phrases started at 31.2% (experimental groups) and 38.7% (comparison groups) on the pretest and ended with 71.9% (experimental groups) and 74.8% (comparison groups) on posttest. There was a gain for both groups of subjects in valid percentage for choosing these terms as completely integrated before, during, and after the treatment took place.

The research hypothesis (H_a) and the statistical hypothesis (H_0) were:

2.1 (H_a: μ_1 > μ_2) Subjects participating in the integrated curricula approach will identify more terms, phrases, and examples of how technology, mathematics, and science are connected in real-world constructs, than those subjects not receiving an integrated curricula approach, as measured by the frequency of terms, phrases, and examples on the posttest instrument.

2.2 (H_0: μ_1 = μ_2) There will be no difference in the number of terms, phrases, and examples identified of how technology, mathematics, and science are connected in real-world constructs on the posttest instrument by the experimental and comparison groups.
Table 3: Frequency of Integrated Terms and/or Phrases

Note: Pow=Power, Amp=Amperage, Hyd=Hydraulic, TE=Thermal Energy

Table 4 displays the statistical data required for testing hypothesis two. An independent samples t-test for both groups was performed on the pretest (pre terms), posttest 1 (post terms 1), posttest 2 (post terms 2), and posttest 3 (post terms 3). The computed t-value was calculated by using SPSS® Version 10.0.5 for Windows®.
<table>
<thead>
<tr>
<th>Instrument/Group</th>
<th>N</th>
<th>Ms</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig. (1-tailed)</th>
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<td>Comparison</td>
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<td>13.11</td>
<td>2.81</td>
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</table>

Table 4: Independent Samples T-Test: Terms and Phrases

Note. The mean score (Ms) was calculated based on a 15-point scale with the higher scores indicating a higher number of terms and/or phrases selected as completely integrated.

No statistically significant differences were found among the pretest, posttest 1, posttest 2, or posttest 3 for the treatment (experimental) and comparison groups at the .05 α level. Therefore, statistical hypothesis two was not rejected. In other words, the treatment did not have a statistically significant effect on the integration orientation (i.e., individual, semi-integrated, or completely integrated terms) of the students.
Table 5 displays the descriptive statistics collected in response to hypothesis three for the experimental and comparison groups on posttest2 and posttest3. The research hypothesis (H_a) and the statistical hypothesis (H_0) were:

3.1 (H_a: \mu_1 > \mu_2) Subjects participating in the integrated curricula approach will have an increase in content retention two and four weeks after the study has been completed, as measured by the mean score on the posttest retention instrument, than those students not receiving an integrated curricula approach.

3.2 (H_0: \mu_1 = \mu_2) There will be no difference in mean scores between the experimental and comparison groups on content retention two and four weeks after the study has been completed, as measured by the mean score on the posttest retention instrument.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
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<th>Mode</th>
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<tr>
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<td>37</td>
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<td>65</td>
<td>61</td>
<td>11.47</td>
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</table>

Table 5: Groups Statistics: Posttest2 and Posttest3

Note. The mean score (Ms) was calculated based on a 100-point scale with the higher scores indicating a higher number of items answered correctly.
Table 6 displays the statistical data required for testing hypothesis three. An independent samples t-test for both groups on posttest2 and posttest3 was performed. The computed t-value was calculated by using SPSS® Version 10.0.5 for Windows®.

<table>
<thead>
<tr>
<th>Instrument/Group</th>
<th>N</th>
<th>Ms</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig. (1-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Exp</td>
<td>37</td>
<td>66.54</td>
<td>18.18</td>
<td>.316</td>
<td>64</td>
<td>.37</td>
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<tr>
<td>Com</td>
<td>29</td>
<td>65.00</td>
<td>21.38</td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Exp</td>
<td>29</td>
<td>65.51</td>
<td>18.48</td>
<td>.214</td>
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</tbody>
</table>

Table 6: Independent Samples T-Test: Posttest2 and Posttest3

No statistically significant differences existed on posttest2 and posttest3 between the treatment (experimental) and comparison groups at the .05 α level. Therefore, statistical hypothesis three was not rejected. In other words, the treatment did not have a statistically significant effect on the retention of student learning two and four weeks following implementation.
CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of chapter five is to present a summary of the research investigation, discuss the results and conclusions, and state recommendations for educational practice.

Summary

The problem the researcher investigated was the integration of technology, mathematics, and science education at the secondary level, taught by a single teacher from technology education. The approach taken by the researcher to investigate this problem and to test theories from the technology, mathematics, and science education fields was one of scientific experimentation completed in the public arena. A high school located in a small suburban village in the United States was purposefully chosen to partake in this research study.

In every experimental study, threats to internal validity are prevalent and need to be controlled to the best ability of the researcher. The researcher was conscious of internal validity threats of history, effect of testing, implementation error, selection, interaction, and experimental mortality, and took every precaution necessary to minimize and/or alleviate these threats. "If not controlled in the experimental design, these
variables might produce effects confounded with the effect of the experimental stimulus” (Campbell & Stanley, 1963, p. 5).

Progressing through the literature review to obtain the necessary background on the subject of integrated teaching and learning in the areas of technology, mathematics, and science education, provided the researcher the background information in developing the following list of research questions that guided this research study. These research questions, then, provided the necessary vehicle for the researcher to develop objectives for the study and resulting research hypotheses.

The research questions for this study were:

1. Does the teaching of high school level integrated technology, mathematics, and science education content and activities, in conjunction with mapped national standards in each of the three subject areas and taught by technology education teachers in technology education laboratories, have an immediate cognitive learning effect and do students have long-term learning retention on technological, mathematical, and scientific problems?

2. How do students view the relationship between mathematical constructs and technology education?

3. How do students view the relationship between scientific constructs and technology education?

4. How do students view the relationship between technological constructs and mathematics and science education?

5. Is retention of content improved over a long-term period through an integrated teaching and learning approach?
The objectives of this study were to:

1. Provide the background, analysis, and evaluation of the methodological, theoretical, and philosophical underpinnings of technology, mathematics, and science education curriculum integration at the high school level;
2. Design and construct hands-on, minds-on activities that focus on and address the mapped national standards in each of three prescribed disciplines;
3. Address selected content and knowledge with an application of an integrated approach to teaching and learning technology, mathematics, and science education; and
4. Assess how students view the relationships between and among technology, mathematics, and science education.

Three hypotheses were tested for this research protocol. The accompanying information discusses the findings for each of these hypotheses. Hypothesis one was stated as:

High school students who are engaged in integrated technology, mathematics, and science education curricula taught by a technology education teacher, will have an increased cognitive learning effect as compared to high school students not receiving an integrated curricula in technology, mathematics, and science education as measured by the mean score on the integrated energy and power technology posttest instrument.

Thirty-nine subjects participated in the pretest and posttest\text{1} in the experimental groups, while 32 subjects participated in the pretest and posttest\text{1} in the comparison groups.

Findings revealed the comparison group had a higher mean score (\text{Ms}) on both the pretest
(before the intervention took place) and posttest1 (after the research intervention)
instruments. An independent samples t-test (Table 2) was used to test hypothesis one.
The researcher concluded that no significant differences existed between the two research
groups and did not reject the statistical (null) hypothesis.

Hypothesis two for this research study was stated as:

Subjects participating in the integrated curricula approach will identify more
terms, phrases, and examples of how technology, mathematics, and science are
connected in real-world constructs, than those subjects not receiving an integrated
curricula approach, as measured by the frequency of terms, phrases, and examples
on the posttest instrument.

Table 3 illustrated the statistical data in response to hypothesis two. The
researcher only provided descriptive data for five of the original 37 terms that appeared
on the pretest instrument. The five terms presented in Table 3 appeared on all four
research instruments and, therefore, were the appropriate terms to analyze on a
continuum. The terms were power, work, amperage, hydraulic, and thermal energy.
Subjects in the experimental and comparison groups chose these five terms as completely
integrated on a more frequent basis after the research protocol was implemented then
before, and two and four weeks after the treatment had taken place. The experimental
group had a valid percent of 31.2 on the pretest and increased to 58.7% on posttest1. For
posttest2, the experimental group had once again increased the valid percent for choosing
these terms as completely integrated to 67.6%. Finally, posttest3 revealed that the
experimental group reached a valid percent of 71.9. The comparison group had similar
increases in their valid percentage: 38.7% (pretest), 55.0% (posttest1), 63.0% (posttest2), and 74.8% (posttest3).

In order to test hypothesis two, the researcher relied on an independent samples t-test (Table 4). The test allowed the researcher to statistically examine how the subjects viewed these terms from the pretest to posttest1, posttest1 to posttest2, and from posttest2 to posttest3. As displayed in Table 4, statistically significant differences did not exist between the groups on the terms and/or phrases. Therefore, statistical hypothesis two was not rejected. It should be noted here that although no significant differences existed between the treatment and comparison groups, there was a change in how students viewed these terms as the research protocol was completed as measured by the valid percent and frequencies in Table 3.

Hypothesis three for this research study was stated as:

Subjects participating in the integrated curricula approach will have an increase in content retention two and four weeks after the study has been completed, as measured by the mean score on the posttest retention instrument, than those students not receiving an integrated curricula approach.

While not statistically significant, the treatment groups had a higher mean score (Ms) on posttest2 and posttest3 than those subjects in the comparison groups (Table 5). To test hypothesis three, an independent samples t-test was utilized. No significant differences existed between the treatment and comparison groups (Table 6). Therefore, statistical hypothesis three was not rejected.
Discussion of Findings

The researcher found it necessary to propose, construct, and implement a study focusing on technology, mathematics, and science education as a curriculum content organizer at the secondary level of education in order to further examine the magnitude and scope of this integrated teaching and learning approach. The researcher believed if a proposed study, such as this, was conducted in the public arena, then the learning outcomes may help validate the integrative approach to teaching and learning. The purpose, of this study, therefore, was to investigate constructivism and brain-based learning in technology, mathematics, and science education curriculum integration through scientific testing in the public arena. Furthermore, the researcher hoped that the outcomes of this research study would help technology educators in developing and implementing an integrated approach of teaching and learning in their classrooms.

Although this study did not produce statistically significant results in the form of improved student learning or content retention of integrated technology, mathematics, and science education, the researcher contends that the study was important and of value; additional theories were investigated.

The fields of technology, mathematics, and science education have all completed standards that reflect the growing concern of integrating their disciplines with those of other disciplines (AAAS: Project 2061, 1993; ITEA: Standards for Technological Literacy: Content for the Study of Technology, 2000; NCTM: Curriculum and Evaluation Standards for School Mathematics, 1989; NRC: National Science Education Standards, 1996; Rutherford & Ahlgren: Science for all Americans, 1990); an increased amount of attention is being given in today's literature to integrated teaching and learning (Beane, 69).
Brusic (1991) posed similar hypotheses as the researcher in this study. Brusic’s study did not yield significant differences between the treatment and control groups on integration as a whole. The researcher concluded that this study was consistent with Brusic’s findings. Brusic, did, however, have statistically significant results from a hypothesis dealing with the increased curiosity level of subjects in the treatment group. This finding is significant for this research study because this researcher, while not looking specifically at curiosity, found that research subjects in the both the treatment and comparison groups chose terms and/or phrases in a completely integrated fashion during and after the research protocol as evidenced by their increased valid percent and frequency in Table 3.

Childress (1994) also posed similar hypotheses as this researcher. Childress did not discover any significant differences between the treatment and control groups, but reported that students did try to implement what they had learned from the science and mathematics instruction when designing technological artifacts and working through technological problem solving. The findings for this research study are consistent with what Childress discovered.
Conclusions

The researcher reached the following three conclusions from this research study after careful examination of the findings presented in Chapter 4:

1. The high school students engaged in integrated technology, mathematics, and science education for this research study do not have an increased cognitive learning effect after the treatment had been implemented. In other words, the treatment did not have a statistically significant effect on student learning immediately following implementation.

2. The high school students engaged in integrated technology, mathematics, and science education for this research study do not choose the open-ended terms and/or phrases as completely integrated in the manner needed for statistically significant results. In other words, the treatment did not have a statistically significant effect on the integration orientation (i.e., individual, semi-integrated, or completely integrated terms) of the students.

3. The high school students engaged in integrated technology, mathematics, and science education for this research study do not have statistically significant increases on retention after the treatment had occurred. In other words, the treatment did not have a statistically significant effect on the retention of student learning two and four weeks following implementation.
Recommendations

The researcher has established the following list of recommendations for further research:

1. The development of an instrument that measures integrated technology, mathematics, and science education is needed to provide the necessary means of assessing student learning. Based on the outcome of this study, the researcher would improve the instrument by changing some of the questions to reflect both the affective and cognitive domains of learning because integrated teaching and learning approaches should not solely rely on forced-choice questions to measure student outcomes. Additional learning opportunities in form of open-ended and problem-solving types of questions should be made available to the students so they can apply the content they have learned in real-world situations.

2. Design a research study that would allow long-term integration efforts (treatment) to take place because this study was only two weeks long and may not have allowed the students the necessary time to fully engage themselves in integrated teaching and learning or the teacher to become comfortable with and proficient in integrated teaching and learning approaches. For example, a nine-week, eighteen-week, or longer period of time would allow more in-depth curriculum to be covered.

3. Design and complete a research study that used three teachers, one each from technology, mathematics, and science education to work cooperatively on a set of integrated themes or integrated curricula. Based on the outcome of this study, the
researcher believes that using three teachers would have enhanced the integrated teaching and learning efforts because of content expertise.

4. Complete integration studies at various high schools, i.e., rural, urban, and suburban to see if any learning effect differences occur. Based on this study, different localities of students may have impacted the findings because school systems may be influenced by the socio-economic make-up of the community, which may often influence what is offered and taught at the high school level.

5. Continue investigating and probing constructivism and brain-based learning as they apply to integrated teaching and learning. The more teachers and researchers can learn about how students think, learn, and interact with curriculum concepts, the stronger student learning levels may be.

6. A qualitative study to capture what students think about technology, mathematics, and science education needs to be completed. Based on this study, the researcher did not examine the intrinsic constructs of research subjects. Ary, Jacobs, and Razavieh (1996) stated “qualitative research . . . seeks a complete understanding of a social phenomenon through the researcher’s total immersion in the situation . . . It may be said that quantitative research seeks explanation, while qualitative research is more concerned with understanding” (pp. 20-21). The rationale behind this recommendation stems from the reasoning that a mix of qualitative and quantitative research may more fully capture how and why students interact within these integrated teaching and learning approaches, thus allowing researchers to make appropriate recommendations for practice.
7. Complete ex-post facto research on schools that offer integrated technology, mathematics, and science education curricula. Examination of schools, teachers, and students involved with integrated teaching and learning may provide additional information for researchers. This additional information may provide new or additional theory on how students and teachers use and apply integrated technology, mathematics, and science education.

8. Based on the outcomes of this study, the researcher would recommend the instruments and curricula material be replicated at several different high schools, despite no significant differences between the treatment and comparison groups. This recommendation stems from the fact that the research protocol was reliable and valid, but did not fully encapsulate integrated teaching and learning. Additional changes to the instrument, however, should be made to reflect a more qualitative, problem-solving appeal. In addition, the researcher would recommend interviewing small groups of students to gain insight toward their thoughts and feelings about integrated teaching and learning.
LIST OF REFERENCES


Gorman, F. H. (1943). An experiment in integrating 7th and 8th grade science mathematics. Science Education. 27, 130-134.


The case for higher standards. (1997, October). *American Teacher, 8*.


Overview

This TMaSe learning lesson and activity will focus on the six forms and ten sources of energy. During this lesson and activity, students will be engaged in the approaches taken to locate, refine, and eventually use energy.

Curricular Objectives

At the completion of this TMaSe learning activity, students will be able to:

- Define the six forms of energy
- Define the ten sources of energy
- List and describe the six forms and ten sources of energy
- Compare and contrast between and among the six forms and ten sources of energy
- Analyze how each source of energy is implemented within the global market
- Assess the benefits and risks of the six forms and ten sources of energy
- Evaluate alternative forms and sources of energy

Procedure

1. Pass out the energy forms/sources handout to each student.

2. Begin this lesson by asking the students how they traveled to school today. After receiving several answers, ask the students what form of energy they used. Again, after receiving several answers, ask the students if they know what source of energy supplied the necessary means of arriving to school. You will probably receive varying answers like “I walked to school”, “I rode my bike to school”, “I drove my car to school”, or “I took the bus to school”. These are all good answers and present a good starting point to discuss forms and sources of energy.

3. Ask the students to name and describe the six forms of energy. Probe the students to construct their own meaning. Have the students write their answers on the “energy forms/sources” handout.

4. After an appropriate amount of time has passed, use the overhead projector and transparencies 2-9, to discuss the six forms of energy.
5. After discussing the six forms of energy, ask the students to name and describe the ten sources of energy. Have the students write their answers on the “energy forms/sources” handout.

6. After an appropriate amount of time has passed, use the overhead projector and transparencies 2-11 to discuss the ten sources of energy.

7. Ask the students if there is a difference between the forms of energy and the sources of energy. After an appropriate amount of time, explain that in order to have “forms of energy”, there needs to be a readily available “source” and vice-versa.

8. Probe the students to see how they feel about the energy forms and sources. What opinions or concerns do they have?

9. After an appropriate amount of time has passed, ask the students about alternative forms of energy that could be used instead of coal and nuclear energy, for example.

10. Using the overhead projector and transparencies 2-16, discuss some the various alternative fuels that are being used and/or tested as alternatives to gasoline for transportation purposes. Ask the students if these alternative energies are realistic in our society and if they believe these types of energy sources will be used in the future.

11. Conclude the lesson by briefly discussing the content.

12. Begin the “Nuclear Energy Activity”. 
Energy Forms

1. 

2. 

3. 

4. 

5. 

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86
6. 

Energy Sources

1. 

2. 

3. 

4. 

87
Introduction

Nuclear Energy is one of the more controversial energy resources being used. One way to analyze many of the issues is to debate the various concepts of nuclear energy. This activity is designed to have you debate the important concepts of nuclear energy and how they relate to our social/economic systems.

To establish a debate on nuclear energy, a difference of opinion must be evident. This can be accomplished, for example, by having one debating team approach a topic from a "consumerist" point of view. The other debating team approaches the issue from a "capitalistic" point of view. The consumerist viewpoint suggests "back to basics, smaller industrial plants, decentralization, environmental emphasis, profits not important," and so forth. The capitalistic viewpoint suggests "profits, large industries, growth, and large corporations."

Procedure

Divide into four equal groups.
Group 1 will portray the consumerist point of view
Group 2 will portray the capitalistic point of view
• Groups 1 and 2 should face one another when the debate starts
Group 3 will develop four questions to be asked to each group
Group 4 will create an evaluation sheet to evaluate the debate

Each group should meet for approximately fifteen minutes to discuss their "plan of action". After the fifteen minutes have expired the debate will begin.

Rules

• Only one person from each group may speak at one time. In addition, if a member of the consumerist group is talking, no one from the capitalistic group may interject. It will be up to the members of Group 3 to help as moderators.
• No name calling or derogative comments should be made to any one person or group.
• The debate will only last twenty minutes.
• At the conclusion of the debate, Group 4 will evaluate Groups 1 and 2 and declare a "DEBATE WINNER".
Overview

This TMaSe learning activity will focus on comparing and contrasting incandescent and fluorescent lamps through a hands-on, minds-on approach, using the Pedal 4 Power™ energy education bike. Fluorescent lamps are an energy efficient lighting source and can be found in, for example, commercial structures like office buildings and institutional structures like schools. Incandescent lamps are not as energy efficient, yet are used in place of fluorescent lamps in almost all residential dwellings in the United States. During this activity, students will generate electricity to compare and contrast these lighting sources using mechanical and electrical energy. Students will be reading volt and ammeters to compare and contrast the energy consumption of the two lighting sources.

Curricular Objectives

At the completion of this TMaSe learning activity, students will be able to:

- Distinguish that lamps convert electrical energy into light and thermal energy
- Compare and contrast the energy efficiency of fluorescent versus incandescent lamps using mechanical and electrical energy
- Define and compute volts, watts, and amps
- Compute Ohm’s Law

Procedure

1. Set up the energy bike and insert the four incandescent and four fluorescent lamps.
2. Flip the ammeter switch located directly above the word WATTS up as indicated in the picture below. The switch located directly under the word AMPS should be placed in the neutral (middle) position and the bank of eight switches on the right side of the board, which operate the lamps, should be in the down (off) position (see picture below).
3. Begin this activity by having students construct their own definitions of electricity, electrical, mechanical, thermal, and light energies. After an appropriate amount of time has passed, discuss these definitions of terms using transparencies 2-11.

4. **Describe the activity:** Students will generate electricity by pedaling the energy bike to compare incandescent and fluorescent lamps. During this activity students will be able to describe how the mechanical energy they are creating and converting to electrical energy, is transformed to thermal and light energy outputs.

5. Have your students predict which type of lamp is more energy efficient and economical.

6. Pass out the data-gathering sheet to each student.

7. Select two volunteers and ask one of them to start pedaling the bike. The other volunteer should stand next to the switches that operate the lamps. The rest of the class should be watching the voltmeter (upper left hand corner of board). Once the voltmeter reaches 12-13 volts, have the second volunteer flip the top fluorescent switch up. The students should record the volts and amps on their data-gathering sheet for one fluorescent lamp.

8. After a few seconds, turn off the fluorescent lamp and switch on an incandescent lamp by flipping the top switch up. The students should record the volts and amps on their data gathering sheet for one incandescent lamp.

9. Stop the bike rider and ask him/her to describe what happened. The rider should indicate the fluorescent lamp was easier to light than the incandescent lamp, but why? *Probe the students to construct their reasoning about what they have seen and felt.*

10. Using the overhead projector and transparencies 12-18, introduce the terms amperage, voltage, watts, Ohm's Law, resistance, and Ohm's Law for Power.
11. Ask two new volunteers to ride the energy bike and operate the switches.

12. The rider should begin pedaling while the other volunteer switches on one fluorescent lamp. The rest of the class should be watching the volt and ammeters. While still pedaling, have the second volunteer switch on one incandescent lamp. The rest of the class should compare how the amperage needed to power the lamps differed. In addition, the students should be paying attention to the "brightness" of the two lamps.

13. *Ask the students which lamp is brighter and why.* The students will probably answer the fluorescent. Remove one fluorescent and incandescent lamp and have the students examine the rated wattage for each. Let the class construct their reasoning behind this result. After an appropriate amount of time, pose the following to the students: *Since there are more watts in an incandescent lamp than a fluorescent lamp, where is the remaining energy going? Why is the fluorescent lamp brighter?*

14. Using the overhead projector and transparencies 19-24, discuss incandescent and fluorescent and the efficiency tables on fluorescent and incandescent lamps.

15. Using two new volunteers, have volunteer one pedal the bike, while volunteer two switches on one fluorescent lamp, then two, three, and finally all four. Have the student riding the bike describe what he/she is feeling. Have the rest of the class watch the volt and ammeters. After a satisfactory period of time, turn off all the fluorescent lamps.

16. Using two new volunteers, have volunteer one pedal the bike, while volunteer two switches on one incandescent lamp, then two, three, and finally all four. Have the student riding the bike describe what he/she is feeling. Have the rest of the class watch the volt and ammeters. After a
satisfactory period of time, turn off all the incandescent lamps.

17. Provide the students with a review of the material that was covered during this lesson.

18. Using the data-gathering sheet, have the students gather in groups of two and complete the written activities.

19. Go over the written activity answers with the students.
## LAMP VS. LAMP
Data Gathering Sheet

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Volts</th>
<th>Amps 1 Lamp</th>
<th>Amps 2 Lamps</th>
<th>Amps 3 Lamps</th>
<th>Amps 4 Lamps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incandescent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Volts</th>
<th>Amps</th>
<th>Watts</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Fluorescent Lamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Incandescent Lamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Calculate how many **watts** each of the two lamps possess using Ohm’s Law for Power and record these numbers in the table above.

2. Calculate the **resistance** of each of the two lamps using Ohm’s Law and record these numbers in the table above.
Overview

This TMaSe learning activity will focus on mechanical and electrical energy in the form of power using the Pedal 4 Power energy education bike. Students will discover how different forms of energy are converted to complete useful tasks. In addition, students will discover that it requires more power to start a motor than to keep one running.

Curricular Objectives

At the completion of this TMaSe learning activity, students will be able to:

- Define power
- Define inertia
- Distinguish the differences between a motor and a generator
- Assess how electrical energy is converted into mechanical energy
- Assess how mechanical energy is converted into electrical energy
- Use capacitors to store electrical energy

Procedure

1. Set up the energy bike.

2. Gather the fan, hair dryer, and plastic bag. Insert the fan and hair dryer into the receptacles on the energy bike board.

3. Pass out to each student the Power data-gathering sheet.

4. Ask the students to construct their own definition of power. After an appropriate amount of time, discuss the definition using the overhead projector and transparency 2.

5. Flip the ammeter switch up as indicated below. All other display board switches, with the exception of the switch located to the right of the terminal posts (this switch is always in the up position unless told otherwise) should be in the off or neutral position.

6. Select two volunteers. The first volunteer should ride the energy
bike while the second volunteer operates the fan.

7. **Ask the class to make an educated guess on how many amps the fan will use on SLOW speed.** As the volunteer is pedaling, have the second volunteer slide the fan switch from OFF to SLOW. **Ask the rider to describe the fan's airflow and the pedaling resistance.** The rest of the class should be observing the ammeter located directing above the word AMPS. Have the students record the amperage on their data-gathering sheet. **The ammeter should be reading about .6 amps for the slow speed and about 1 amp for the fast speed.**

8. **Ask the class to make an educated guess on how many amps the fan will use on FAST speed.** While the student continues to pedal, slide the fan switch to FAST. The student may feel an increase in the pedaling resistance. Again, have the rest of the class observe the ammeter and record the amperage on their data-gathering sheet. **The ammeter should be reading about .6 amps for the slow speed and about 1 amp for the fast speed.**

9. Using the overhead projector and transparencies 3-5, discuss with the students amperage, electrical, and mechanical energy.

10. Place the plastic bag over the fan so that it is stretched tightly over the grill.

11. Ask for two new volunteers. Again, one for pedaling and the other for operating switches and appliances. Turn the fan on FAST and have the bike rider start pedaling until he/she reaches 12-13 volts. The rest of
the class should be watching the ammeter and recording the meter reading on their data-gathering sheet. *Ask the students to construct a reason behind the different meter readings. The amount of current will be higher because the fan must work harder to move the air against the bag.*

12. Remove the plastic bag. Have the rider continue to pedal while the other volunteer switches the fan to OFF. Wait until the fan stops then switch it back to FAST. Have the class watch closely because the ammeter should surge to more than 2 amps before settling down to 1 amp.

13. *Ask the students to define inertia.* After an appropriate amount of time has passed, discuss the definition using the overhead projector and transparencies 6 and 7. *Due to inertia, more energy is required to start a motor than to keep it running.*

14. Ask for two new volunteers. Ask the class to predict the number of amps the hair dryer will use based on their experience with the fan.

15. Flip the ammeter switch down towards the 0-30 ammeter to accurately measure the number of amps used by the hair dryer. See picture below.

16. Have the rider start pedaling the bicycle. After the voltmeter reads 12-13 volts, have the other volunteer switch on the hair dryer. Have the rest of the class observe the meter and record the
amperage on their data-gathering sheet.

17. Ask the class which motor moved the most air? Typically, the fan will move a much greater amount of air, but why?

18. Ask the class why the hair dryer uses so much more energy yet produces less air? The hair dryer heats air with a resistive element similar to the one found in a toaster.

19. Turn off the hair dryer.

20. Using the overhead projector and transparencies 8 and 9, discuss resistance/resistive products.

21. Using the overhead projector and transparencies 10 and 11, discuss generators and motors.

22. Flip the ammeter switch to the off (neutral) position.

23. Select two new volunteers. The rider should pedal the bike until he/she reaches 12-13 volts. Once the volunteer has reached this voltage, the other volunteer should switch the meter shown below to the up position. This will enable the capacitors to start charging.

24. While the student is pedaling, ask the rest of the class what a capacitor is and what role it plays?

25. Again, while the student is pedaling, the rest of the class should be observing the 0-5 ammeter. The meter should be moving back toward the zero mark, which shows the capacitors are charging. Once
the meter reaches zero, the

capacitors are charged; have the
rider stop pedaling.

26. Using the overhead projector and transparencies 12-14, discuss what a capacitor is.

27. **Ask the students if there is**

   **enough electrical charge stored in the capacitors to turn electrical energy into mechanical energy for purposes of running the fan?**

28. Get out the stopwatch that is in the energy bike case. Have a student reset the stopwatch to zero if necessary. The bike rider, at this point, should not be pedaling. Have the other volunteer switch the fan to SLOW. Begin timing the fan. Let the fan run as long as the capacitors have an electric charge. The rest of the class should be observing and recording this information on their data collection sheet.

   **Reinforce how electrical energy is converted to mechanical energy.**

29. Turn off the fan.

30. Ask for two new volunteers. Repeat the process of charging the capacitors.

31. Install the cassette player into a receptacle.

32. Ask for two new volunteers.

33. Ask the students if the radio will run longer or shorter than the fan?

34. Using the same procedure for charging the capacitors and timing the appliance, run the radio for as long as it will go. Record this information on the data-gathering sheet.
35. Review this lesson by asking if there are any questions. Review the activity in such a way to reinforce the content that was presented.
# POWER
Data Gathering Sheet

<table>
<thead>
<tr>
<th>Volts</th>
<th>Amps</th>
<th>Watts</th>
<th>Time</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan (Slow)</td>
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<tr>
<td>Fan (Fast)</td>
<td></td>
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<tr>
<td>Fan (with bag)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Hair Dryer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

1. Calculate how many **watts** the fan, hair dryer, and radio use using Ohm’s Law for Power and record these numbers in the table above.

2. Calculate the fan, hair dryer, and radio **resistance** using Ohm’s Law and record these numbers in the table above.
Overview

This TMaSe learning activity will focus on capacitors. Students will discover how capacitors work, how they differ from batteries, and why potential and kinetic energies must be understood when designing and/or using electrical devices. Students will discover these concepts using the Pedal 4 Power™ energy education bike.

Curricular Objectives

At the completion of this TMaSe learning activity, students will be able to:

- Distinguish the difference between capacitors and batteries
- Analyze how potential and kinetic energies are used
- Compute watts for different products
- List how capacitors are used in other products

Procedure

1. Set up the energy bike.
2. Insert the four fluorescent lamps in the lamp bases as shown below.
3. Pass out to each student the Storing Energy data-gathering sheet.
4. Flip the ammeter switch up as shown below. All other switches should be off or in the neutral position, with the exception of the switch located to the right of the terminal posts (this switch is always in the up position unless told otherwise).
5. Ask the students to construct their own meaning of what a capacitor is. After an
appropriate amount of time,

discuss the definition using the
overhead projector and
transparencies 2-3.

6. Ask the students to construct
their own meaning of what a
battery is. After an appropriate
amount of time, discuss the
definition using the overhead
projector and transparencies 4-5.

7. Ask the students to now describe
the differences between
capacitors and batteries. After
an appropriate amount of time,
show the students the chart
comparing capacitors and
batteries. This chart can be
found on transparency 6.

8. Ask for two volunteers. One
volunteer will ride the energy
bike while the other operates the
switches.

9. Flip the top ammeter switch to
the center (off) position (see
picture below).

10. Have the rider start to pedal.
Once he/she reaches 12-13 volts,
charge the capacitors by flipping
the switch indicated below.

11. Ask the class to observe the
voltmeter. Ask the class to
construct their own meaning of
what potential energy is.
Typically, when the energy bike is not being pedaled, the voltmeter will register zero. However, due to the potential energy stored in the capacitors, the voltmeter will register 10-12 volts.

12. Using the overhead projector and transparency 7, discuss potential energy.

13. Ask the students how the energy bike stores its potential energy? The electrons are stored in the energy bike’s capacitors.

14. Plug in the radio/cassette player. Ask a volunteer from the class to use the stopwatch found in the energy bike case. Ask the students to decide if the radio will use more energy than the cassette tape? Play the radio and have the volunteer time how long it takes for the capacitors to completely discharge. The rest of the class should be observing what is happening and writing down the time and how many amps the radio is using (amps will be minimal .05) on their data-gathering sheet. Since the amperage for the radio is minimal on the 0-5 ammeter, switch to the milliammeter by flipping the switch down, as indicated by the picture below.

15. Ask for two new volunteers. Again, turn all the switches off. Charge the capacitors again. This time, put in the cassette that is located in the energy bike case. Start the tape player and have the students time how long it takes to
discharge the capacitors and how many amps the tape player is using. Have the students fill in this information on their data-gathering sheet. Again, use the milliammeter to get an accurate amp reading.

16. While the tape player is playing, adjust the volume up. Have the students watch the milliammeter. *Why did the amperage go up?*

*The louder the volume, the more amps are needed. Turn the volume down and watch the ammeter adjust.*

17. Using the data-gathering sheet and appropriate transparency, show the students how watts are calculated and then have them compute how many watts the tape player requires.

18. *Referring back to potential energy, ask the students about kinetic energy.* Using transparency 8, show the students the definition of kinetic energy.

19. Unplug the radio/cassette player.

20. Ask for two new volunteers.

21. Use the same procedure for charging the capacitors. This time, however, turn one of the fluorescent lamps on. Have the students time how long it takes the lamp to discharge the capacitors. The students should record this time on their data-gathering sheet. In addition, have the students calculate how many watts one lamp uses.

22. Experiment with how many fluorescent lamps the capacitors can drive.

23. Install one incandescent lamp and repeat the procedure. *The incandescent lamp will barely*
emit light if any. Ask the students why.

24. Once you have completed these activities, the capacitors need to be fully discharged. Follow the procedure listed below.

• Flip the top ammeter switch to the center position.
• Flip the capacitor switch up.
• Turn on an incandescent lamp until the voltmeter reaches zero.
• Flip the capacitor switch to the center position.

25. Discuss with your students some ways in which capacitors are used. Refer to transparency 9.

26. Return all products to the energy bike case.

27. Review the lesson and go over the answers the students have on their data-gathering sheet.
## STORING ENERGY
### Data Gathering Sheet

<table>
<thead>
<tr>
<th></th>
<th>Volts</th>
<th>Watts</th>
<th>Amps</th>
<th>Time</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassette Player</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fl. Lamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Calculate how many watts the radio, cassette player, and one fluorescent lamp using **Ohm's Law for Power** and record these numbers in the table above.

2. Calculate the radio, cassette player, and fluorescent lamp resistance using **Ohm's Law** and record these numbers in the table above.
Overview

This TMaSe learning activity will focus on resistance, fuses, and circuit breakers. Students will be involved with hands-on, minds-on concepts that focus on safety, wire gauge, and how circuits can be overloaded.

Curricular Objectives

At the completion of this TMaSe activity, students will be able to:

- Analyze how circuit breakers and fuses work
- Distinguish the differences between different gauge wires and length of these wires
- Recognize how resistance plays a significant role in electrical usage

Procedure

1. Set up the energy bike and insert all eight lamps, 6 amp fuse, hair dryer, and fan. Also, gather the three spools of wire that are located in the energy bike case.

2. Pass out the data-gathering sheet for this activity.

3. Flip the ammeter switch up as indicated in the picture below.

4. Ask for two volunteers. One volunteer should be the bike rider, while the other operates the switches on the board.

5. Have the volunteer start pedaling the bike. Have the other person switch on one incandescent lamp, then two, three, and finally all four. The rest of the class should be watching the volt and ammeters. Have the rest of the class calculate how many watts one, two, three, and four incandescent lamp produces on
their data-gathering sheet. Their calculations for one lamp should be **12 Volts x 4 Amps = 48 Watts**

**Watts** Have this student pedal for a couple of seconds for each lamp and then turn the lamps off.

**You can also use the fan, hair dryer, and fluorescent lamps, but make sure they are used individually.**

6. Uncoil the 14 gauge wire from one of the spools. Place one end of the wire in the lower left terminal post. Place the other end of the wire in the lower right terminal post. Move the switch located to the right of the terminal posts down (see picture below).

7. Have the bike rider start pedaling while the other volunteer switches on one incandescent lamp, then two, three, and finally all four. Have the rest of the class watch the volt and ammeters and record the volts and amps on their data-gathering sheet and compute the watts. **There should be a small difference in amperage found by the students.**

8. Select two new volunteers.

9. Take the 14 gauge wire out of the terminal posts and recoil the wire.
10. Uncoil the 22 gauge wire and repeat the process. There should be a noticeable difference in the amperage.

11. Select two new volunteers.

12. Take the 22 gauge wire out of the terminal posts and recoil the wire.

13. Repeat this part of the activity with the 28 gauge wire. Again, have the students record their data and compute the necessary formulas.

14. Remove the 28 gauge wire and recoil it.

15. If you used the fan, hair dryer, and fluorescent lamps, have the students compute the necessary information on their data-gathering sheet.

16. Ask the students to construct their own reasoning behind the different electrical outputs they have witnessed. Explain to the class that the red wire in the top two terminal posts is 16 gauge and all the wiring on the back of the board is 16 gauge. Therefore, resistance is not really seen or understood until a different gauge wire is used in its place.

17. Insert a 20 amp fuse in the fuse block and move the alligator clips from the circuit breaker to each end of the fuse block. See Picture Below

18. Ask for two new volunteers.

19. Insert a piece of the 30 gauge wire into the lower terminal posts. You can find this wire in a
zip lock bag in the energy bike case.

20. **The student pedaling the bike is going to create a significant load across the 30 gauge wire causing it to burn. Do not tell the students what is going to happen, but keep them clear of the wire.** See Picture Below.

21. Have one volunteer start pedaling while the other volunteer switches on one incandescent lamp, then two, three, and finally all four. Have the students keep an eye on the 30 gauge wire.

After a few seconds, the wire will burn.

22. **Ask your students why the wire burned.**

23. Flip the terminal post switch up. Once the wire has cooled, release it from the lower terminal posts.

24. Replace the 20 amp fuse with a 6 amp fuse.

25. Ask for two new volunteers.

26. Have the bike rider start to pedal while the other volunteer switches on one incandescent lamp and the hair dryer. The current should blow the fuse.

If for some reason the fuse does not blow, turn on a second incandescent lamp.

27. Ask for two new volunteers.

28. Have the bike rider start to pedal and have the other volunteer switch on one incandescent lamp.

**Ask the class if what they are**
observing is a closed or open circuit. Stop the bike rider and remove the wire between the top two terminal posts. Have the bike rider start to pedal and have the other volunteer switch on one incandescent lamp. The lamp should not turn on. Ask the class if what they are observing is a closed or open circuit.

29. Reinstall the wire in the top two terminal posts.

30. Return all parts to the energy bike case.

31. Review the material covered in this lesson and discuss the data-gathering sheet.
# RESISTANCE AND MORE

**Data Gathering Sheet**

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Volts</th>
<th>Amps</th>
<th>Watts</th>
<th>Resistance</th>
<th>14 GA</th>
<th>22 GA</th>
<th>22 GA</th>
<th>28 GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Incandescent Lamp</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>2 Incandescent Lamps</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Incandescent Lamps</td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>4 Incandescent Lamps</td>
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<td></td>
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<tr>
<td>Fan</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hair Dryer</td>
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<td></td>
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<tr>
<td>Radio</td>
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</tr>
</tbody>
</table>
Overview

This TMaSe learning lesson and activity will focus on how bicycles and gears work by examining mechanical advantage and velocity ratio.

Curricular Objectives

At the completion of this TMaSe learning activity, students will be able to:

- Use problem solving skills to solve technological problems related to gears
- Apply mathematical and scientific formulas to solve equations
- Collect and analyze data
- Describe the advantages and disadvantages of bicycles as a measure of transportation

Procedure

1. Pass out the gear and shifting calculations sheet to each student.
2. Begin this lesson by asking students what they currently know about bicycles and gears.
   After an appropriate amount of time, use the overhead projector and “Gears and Bicycle Parts” transparencies 2-6 to discuss the bicycle gearing systems.
3. Using the overhead projector and “Mechanical Advantage and More” transparencies 2-6, discuss mechanical advantage and velocity ratio.
4. Remove the energy bike from the bike stand and set it up in such a way that you can measure the distance the pedal travels in one complete revolution.
5. Set a tape measure on the floor and pull out around 15’. At the same time, try to keep the tape measure parallel to a school/lab wall.
6. Place the gearshift lever in the first or lowest gear.
7. Mark the starting point on the floor.
8. Rotate the pedal exactly one revolution.
9. When the bicycle stops, mark the end of the distance.
10. Measure the distance from the start to the end of the distance the bicycle traveled.
11. Using another tape measure, measure the pedal radius. This is
achieved by measuring the
distance from the center of the
sprocket (driver gear) to the
center of the pedal axis — this is
the pedal radius.

12. Have the students calculate the mechanical advantage (MA) for that gear. Was there a mechanical advantage?

13. Using the overhead projector and “Gears and Bicycle Parts” transparency 7 show the students a gear and shifting legend developed for this bicycle.

14. Using transparency 9, compare the students’ results with the legend. Notice that there is neither a mechanical advantage nor loss of mechanical advantage because the input and output were the same.

15. Using transparency 9 and 10, go through each of the different gears.

16. After the students have become accustomed to how each of the formulas work and how the legend is formatted, have them complete the legend for gears 15-21.

17. After an appropriate amount of time, share transparency 11 with the students comparing their answers to yours.


19. To conclude this lesson, each student should answer the following questions:

- When a gain of torque or starting power is developed using the gears on a bicycle, what is given up or lost?
- Which gear produces the greatest amount of torque?
- Which gear produces the greatest amount of distance?
- Besides a bicycle, where else are gears used?
BIBLIOGRAPHY


Thank you for agreeing to participate in this research study. Please take a moment to read the directions for completing the various portions of this instrument.

**Section One**

**Directions:** For section one of this instrument you will be asked to read and respond to a series of general questions. Located below each question you will find several possible answers. Please shade in the square next to the answer of your choice or write in a response in the appropriate area.

Example: My favorite professional football team is the ___________.

- Chicago Bears
- Pittsburgh Steelers
- Denver Broncos
- Green Bay Packers

1. What is your current grade (level) in high school?
   - Freshmen (9th grade)
   - Sophomore (10th grade)
   - Junior (11th grade)
   - Senior (12th grade)

2. What is your gender?
   - Male
   - Female

3. What mathematics course(s) have you completed or are currently taking? (check all that apply)
   - Pre-Algebra
   - Algebra 2
   - Geometry
   - Algebra 1
   - Algebra 3
   - Informal Geometry
   - Other ___________________________
4. What science course(s) have you completed or are currently taking? (check all that apply)

- [ ] General Science
- [ ] Biology 1-A
- [ ] Biology 1-B
- [ ] Biology 2
- [ ] Chemistry 1
- [ ] Chemistry 2
- [ ] Physics
- [ ] Adv. Science Seminar
- [ ] Other ____________________________

5. What industrial/technology education course(s) have you completed or are currently taking? (check all that apply)

- [ ] Ind. Ed. Orientation
- [ ] Intro. Graphic Design
- [ ] CAD Drawing 1
- [ ] CAD Drawing 2
- [ ] CAD Drawing 3
- [ ] Construction
- [ ] Pre-Engineering 1
- [ ] Pre-Engineering 2
- [ ] Woods 1
- [ ] Woods 2
- [ ] Other ____________________________
Section Two

Directions: For section two of this instrument you will be asked to read and respond to a series of questions relating to energy and power technology. After carefully reading each question, you should choose **one** answer. Please **answer all questions** even if you do not know the answer 100%. Located below each question you will find several possible answers. Please shade in the square next to the answer of your choice. Again, please choose only **one** answer.

6. There are _____ forms of energy.
   - [ ] 2
   - [ ] 3
   - [ ] 5
   - [ ] 6

7. There are _____ sources of energy.
   - [ ] 6
   - [ ] 8
   - [ ] 9
   - [ ] 10

8. _____ energy is usually derived from the fission or splitting of certain heavy, unstable atoms.
   - [ ] Radiant
   - [ ] Nuclear
   - [ ] Electrical
   - [ ] Chemical

9. _____ energy may be natural, as in the sun, or artificial, such as the light from a camera flash.
   - [ ] Radiant
   - [ ] Mechanical
   - [ ] Chemical
   - [ ] Nuclear
10. _____ energy is stored in the bonds between the atoms of food, wood, coal, and other fuels.

- Thermal
- Electrical
- Chemical
- Petroleum

11. _____ energy can be described as an electromotive force. This type of energy is produced from a flow of electrons from atom to atom.

- Radiant
- Thermal
- Biomass
- Electrical

12. _____ energy is related to heat. This type of energy is produced by moving or vibrating molecules.

- Propane
- Coal
- Thermal
- Light

13. _____ energy is the energy of motion used to perform work. This type of energy pulls, pushes, twists, turns, and throws.

- Mechanical
- Solar
- Electrical
- Photovoltaic

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14. _____ is a fossil fuel in the form of black rock. This energy source is primarily used for producing electricity.

- Hydropower
- Coal
- Petroleum
- Propane

15. _____ is a fuel refined from natural gas.

- Coal
- Biomass
- Natural Gas
- Propane

16. _____ is a colorless, odorless fossil fuel mostly made of methane.

- Propane
- Natural Gas
- Geothermal
- Biomass

17. _____ results from the uneven heating of the earth and its atmosphere from the sun.

- Geothermal
- Wind
- Solar Energy
- Nuclear Energy

18. _____ is a nondepletable or renewable energy source.

- Coal
- Petroleum
- Geothermal
- Natural Gas
19. _____ is the energy source produced by moving water.
   - Biomass
   - Hydropower
   - Solar
   - Nuclear

20. All organic materials can be used as a _____ energy source.
   - Biomass
   - Hydropower
   - Nuclear
   - Solar

21. _____ is the primary energy source used in the United States for purposes of electrical generation.
   - Nuclear
   - Propane
   - Coal
   - Geothermal

22. _____ can be defined as the forced movement of electrons from atom to atom.
   - Electricity
   - Amperage
   - Voltage
   - Resistance

23. _____ can be defined as a negatively charged particle that revolves around the nucleus of an atom.
   - Electrons
   - Protons
   - Neutrons
   - Particles
24. An _____ is a positive charge in the nucleus of an atom.

☐ Electron
☐ Proton
☐ Neutron
☐ Particle

25. The amount of the negative charge of each _____ is equal to the amount of the positive charge of each _____.

☐ electron, proton
☐ proton, electron
☐ neutron, particles
☐ particles, neutron

26. _____ is defined as the ability to do work.

☐ Power
☐ Energy
☐ Electricity
☐ Torque

27. _____ energy is defined as the ability to store energy.

☐ Kinetic
☐ Potential
☐ Thermal
☐ Radiant

28. _____ energy is defined as energy of motion.

☐ Kinetic
☐ Potential
☐ Radiant
☐ Thermal
29. _____ is defined as the amount of electrons flowing from a negative point to a positive point in a given period of time. It is also referred to as current.
- Voltage
- Amperage
- Resistance
- Watts

30. _____ is defined as the push or force used to move electrons; the unit for expressing electromotive force.
- Voltage
- Amperage
- Watts
- Power

31. _____ is defined as opposition to electric current flow.
- Amperage
- Watts
- Resistance
- Power

32. _____ is a measure of power used in a circuit.
- Amperage
- Voltage
- Resistance
- Watts

33. Which mathematical formula would be correct in using if one wanted to know the “power” of a given circuit?
- Ohm’s Law
- Ohm’s Law for Power
- Voltage multiplied by resistance
- Voltage squared
34. Which mathematical formula would be correct in using if one wanted to know the resistance of a given circuit?

□ Ohm’s Law
□ Ohm’s Law for Power
□ Amperage multiplied by resistance
□ Resistance squared

35. _____ lamps produce light by heating a filament to a white-hot temperature.

□ Fluorescent
□ Incandescent
□ Mercury Vapor
□ Ballast

36. _____ lamps produce light by the action of ultraviolet rays striking a phosphor-coated surface.

□ Fluorescent
□ Incandescent
□ Efficient
□ Ballast

37. Incandescent lamps are more energy efficient than fluorescent lamps because they are inexpensive to purchase.

□ True
□ False

38. Under normal usage, incandescent lamps last five times longer than fluorescent lamps.

□ True
□ False
39. The sluggishness or apparent resistance an object offers to changes in its state of motion is referred to as _____.

☐ mechanical energy
☐ inertia
☒ torque
☐ electrical energy

40. Motors and generators have the same physical construction. Each consists of a conductive coil called an armature, which rotates in an electromagnetic field to create electricity.

☐ True
☐ False

41. _____ are usually used to provide a mechanical advantage.

☐ Generators
☐ Motors
☐ Inertia pellets
☐ Coal particles

42. _____ are used to produce electrical energy.

☐ Generators
☐ Motors
☐ Inertia pellets
☐ Derailleurs
43. _____ are made of two conductive plates separated by an insulating material called a dielectric. The two plates are attached to the terminals of an electrical source: one plate to the positive terminal and the other to the negative terminal. One of chief components of this electrical device is the ability to store energy and when acted upon instantaneously release energy. This device, for example, can be found in photographic cameras.

- Resistors
- Circuit boards
- Capacitors
- Diodes

44. A _____ converts stored chemical energy into electrical energy for use in various applications.

- capacitor
- generator
- battery
- motor

45. _____ can be defined as a ratio between load and effort.

- Velocity ratio
- Mechanical advantage
- Gear ratio
- Gear train

46. _____ is the relationship between the distance moved by the effort and load.

- Velocity ratio
- Mechanical advantage
- Gear ratio
- Gear train

47. Gears are toothed wheels fixed to an axle.

- True
- False
48. When calculating gear ratio, one must know the output (driven teeth) and the input (driver teeth). The formula for calculating gear ratio is:

\[
GR = \frac{\text{Number of driven teeth (output)}}{\text{Number of driver teeth (input)}}
\]

For example, if one wanted to find out the gear ratio of an output gear with 16 teeth and an input gear with 12 teeth, one could use the formula above. The answer that would result is 1.333. Therefore, in this example, the gear ratio would be stated as 1.333:1. The question, then, is what does a gear ratio of 1.333:1 illustrate?

□ For every one revolution of the input gear, the output gear rotates 1.333 times
□ For every one revolution of the output gear, the input gear rotates 1.333 times
□ For every one revolution of the input gear, the output gear rotates 1 time
□ Neither of these answers

49. Which type of gear system does a bicycle use?

□ Sprocket and chain
□ Worm gear
□ Rack and pinion
□ Screw

50. _____ is described as the rate at which the output work is being done in a mechanical system. It is also a unit or measure of the work done with a certain time limit.

□ Horsepower
□ Inertia
□ Torque
□ Force
51. _____ tends to change the motion of things.
   □  Force
   □  Torque
   □  Horsepower
   □  Inertia

52. _____ tends to twist or change the rotation of things.
   □  Force
   □  Torque
   □  Horsepower
   □  Inertia
Directions: For section three of this instrument you will be asked to read and compute a series of mathematical questions relating to energy and power technology. After carefully reading each question and completing your computations, you should choose one answer. Please answer all questions even if you do not know the answer 100%. Located below each question you will find several possible answers. Please shade in the square next to the answer of your choice. Again, please choose only one answer.

53. Using the Ohm’s Law for Power formula (attached at the end of this instrument) complete the following question: How many watts does the following circuit use if the input device generates 12 volts at 6 amps?
   □ 72 Watts
   □ 2 Watts
   □ .5 Watts
   □ 12 Watts

54. Using the Ohm’s Law for Power formula, complete the following question: What would be the voltage of a circuit in which the wattage was 50 and the amperage was 9?
   □ .18 Volts
   □ 5.55 Volts
   □ 450 Volts
   □ .163 Volts

55. Using the Ohm’s Law for Power formula, complete the following question: What would be the amperage of a circuit in which the wattage was 60 and the voltage was 120?
   □ .5 Amps
   □ 2 Amps
   □ 7200 Amps
   □ 5000 Amps
56. Using the **Ohm's Law** formula (attached at the end of this instrument) complete the following question: What would be the resistance if an electrical circuit possessed 120 volts and 17 amps?

- □ 7.05 Ohms
- □ .14 Ohms
- □ 2040 Ohms
- □ 130.69 Ohms

57. Using the **Ohm's Law** formula, complete the following question: What would be the voltage of an electrical circuit if there were 20 amps and a resistance of 75 ohms?

- □ .26 Volts
- □ 3.75 Volts
- □ 1,500 Volts
- □ 15,000 Volts

58. Using the **Ohm's Law** formula, complete the following question: What would be the amperage of an electrical circuit if there were 240 volts and a resistance of 95 ohms?

- □ 2.52 Amps
- □ .395 Amps
- □ 25.2 Amps
- □ 22,800 Amps

59. Using the **Mechanical Advantage** formula (attached at the end of this instrument) complete the following question: What would be the mechanical advantage where 60 pounds of effort was exerted to lift 140 pounds of steel?

- □ 8,400
- □ 14,400
- □ .428
- □ 2.33
60. From the answer you derived from question 59, would you have a mechanical advantage in that a gain in output force has been achieved?

- Yes
- No

61. Using the **Gear Ratio** formula (attached at the end of this instrument) complete the following question: What would be the gear ratio for a bicycle that used an output gear with 13 teeth and an input gear with 48 teeth?

- .27:1
- 3.69:1
- 6.24:1
- 1:1

62. Using the **Horsepower** formula (attached at the end of this instrument) complete the following question: What would be the horsepower of a motorcycle that exhibited 150 foot pounds of torque and the rear tire rotated 360 times per minute?

- 10.28 Horsepower
- .97 Horsepower
- 28,360 Horsepower
- 13 Horsepower

63. Using the **Torque** formula (attached at the end of this instrument) complete the following question: What would be the torque if a 20 pound weight traveled 6.75 inches?

- 135
- 13,500
- 2.96
- .337
**Section Four**

**Directions:** For section four of this instrument you will be asked to read a series of terms and phrases relating to energy and power technology. After carefully reading each term and/or phrase, decide whether you think the term and/or phrase represents mathematics, science, or technology or a combination of two or describes all three. Next to each term and/or phrase there are four boxes with the letters T, S, M, or A. The “T” stands for technology, the “S” stands for science, the “M” stands for mathematics, and the “A” stands for all. Shade in as many boxes that apply to the term/phrase.

Example:

<table>
<thead>
<tr>
<th>Term</th>
<th>Technology</th>
<th>Science</th>
<th>Mathematics</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Chair</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>Pythagorean Theorem</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>Newton’s Laws of Motion</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>Fiber Optic Cables</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
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</table>

<table>
<thead>
<tr>
<th>Term</th>
<th>Technology</th>
<th>Science</th>
<th>Mathematics</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>64. Force, Mass, and Acceleration</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>65. Horsepower</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>66. Watts</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>67. Power</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>68. Velocity</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>69. Work</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>70. Resistance</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>71. Mechanical Advantage</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>72. Gear Ratio</td>
<td>T</td>
<td>S</td>
<td>M</td>
<td>A</td>
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<td></td>
<td></td>
<td>Technology</td>
<td>Science</td>
<td>Mathematics</td>
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<tr>
<td>73.</td>
<td>Lever</td>
<td>T O S D M O A O</td>
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<tr>
<td>74.</td>
<td>Wheel and Axle</td>
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<td>75.</td>
<td>Pulley</td>
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<td>76.</td>
<td>Inclined Plane</td>
<td>T O S D M O A O</td>
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<td>77.</td>
<td>Wedge</td>
<td>T O S D M O A O</td>
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<td>Screw</td>
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<tr>
<td>82.</td>
<td>Forced movement of electrons</td>
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<tr>
<td>83.</td>
<td>Nuclear</td>
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<tr>
<td>84.</td>
<td>Aerodynamics</td>
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<td>Coefficient of Drag</td>
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<td>Diode</td>
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<td>Hydroelectric</td>
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<tr>
<td>88.</td>
<td>Pneumatic</td>
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<td>89.</td>
<td>Hydraulic</td>
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<tr>
<td>91.</td>
<td>Electrical Energy</td>
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<tr>
<td>92.</td>
<td>Thrust</td>
<td>T O S D M O A O</td>
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<tr>
<td>93.</td>
<td>Turbine</td>
<td>T O S D M O A O</td>
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<tr>
<td>94.</td>
<td>Voltage</td>
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<td>95.</td>
<td>Bernoulli’s Theorem</td>
<td>T O S D M O A O</td>
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<td>Energy</td>
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<td>97.</td>
<td>Capacitors</td>
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<tr>
<td>98.</td>
<td>Mechanical Energy</td>
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<tr>
<td>99.</td>
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<tr>
<td>100.</td>
<td>Inertia</td>
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</table>
APPLICATION FOR EXEMPTION FROM HUMAN SUBJECTS COMMITTEE REVIEW

All research activities that will involve human beings as research subjects must be reviewed and approved by the appropriate human subjects review committee, or receive exemption status, prior to implementation of the research.

Principal Investigator: Scott, Michael L.
Academic Title: Associate Professor
Department: School of Teaching and Learning
Campus Address: Suite 100 1100 Kinnear Road
Co-Investigator(s): Merrill, Christopher P.

PROTOCOL TITLE: Effects of Integrated Technology, Mathematics, and Science Education on Secondary School Technology Education Teachers and Students

THE ONLY INVOLVEMENT OF HUMAN SUBJECTS IN THE PROPOSED RESEARCH ACTIVITY WILL BE IN ONE OR MORE OF THE EXEMPTION CATEGORIES LISTED ON THE BACK OF THIS APPLICATION.

CATEGORY: (Check one or more) #1 X #2 #3 #4 #5 #6

SOURCE OF FUNDING FOR PROPOSED RESEARCH: (Check A or B)
A. OSURF: Sponsor __________________________ RF Proposal/Project No. __________________________
B. Other (Identify) Self-funded

EXEMPTION STATUS. ✓ APPROVED □ DISAPPROVED**

2/1/2000

** Principal Investigator must submit a protocol to the appropriate Human Subjects Review Committee.

IMPORTANT NOTICE TO INVESTIGATORS: Exempting an activity from review DOES NOT absolve the investigators of the activity from ensuring that the welfare of human subjects in the activity is protected and that methods used, and information provided, to gain subject consent are appropriate to the activity.
February 1, 2000

Dear Parent/Guardian,

My name is Chris Merrill and I am a Doctoral Candidate at The Ohio State University in Columbus, Ohio and a 1987 graduate of _____ High School. The reasons for this letter are to inform you of a teaching and learning research project your son/daughter can voluntarily participate in during Mr. _____ industrial/technology education classes this February, and to ask your permission to allow your son/daughter to participate. As a researcher, public school teacher, and graduate teaching associate, I am interested in seeing whether an integrated mathematics, science, and technology education curricula, focusing on energy and power technology and used in conjunction with hands-on learning, will have a positive learning effect on students. Your son/daughter would attend class normally and simply participate in each activity. No additional work inside or outside of class would result from your son/daughter participating. This project should only last approximately ten class periods or two weeks. In addition, you can be assured your son/daughter’s education will not be diminished because of this research. As part of this research project your son/daughter would be asked to complete pretest and post-test assessments on four occasions. These scores will not be counted toward your child’s grade, but used strictly for statistical analysis.

The curriculum that I intend to use in this research project is part of the state and national curriculum for industrial/technology education. Your son/daughter would normally receive this curriculum in their industrial/technology education classes at _____ High School. The curriculum would be taught by Mr. _____, the industrial/technology education teacher at _____ High School. If your son/daughter does not want to participate or you do not want them to participate, alternative teaching and learning exercises would be provided by Mr. _____ that would follow the normal curriculum your son/daughter is receiving.

No physical or mental harm would come to your child nor would your child be identified by name in any research findings or publications. In fact, _____ High School would only be named as a “Suburban Village High School in the Midwest”. I have insured Mr. _____, the school principal, that all parties involved would remain anonymous, student participation is strictly voluntary, and that I would share any research results with the school board or any parent/guardian that would be interested. Upon completion of this research project at _____ High School, I will donate an exciting, hands-on, Energy Bike that retails for $3,000. This Energy Bike is an integral part of the research project I am proposing to complete. If you would like more information about
this research project, I would be more than willing to share my thoughts and ideas. You can contact me at the above telephone number or by e-mail at Merrill.22@osu.edu.

Sincerely,

Chris Merrill
Doctoral Candidate
The Ohio State University

Michael L. Scott, Ph.D.
Research Advisor
The Ohio State University

In the boxes below, please indicate whether you would or would not be willing to allow your son/daughter to participate in this research project. If you choose not to allow your son/daughter to participate, alternative teaching and learning exercises prescribed by Mr. _____ would be assigned. Also, please find two lines below the participation choices.

On the first line, please print your son/daughter’s name. On the second line, please sign your name. Please give this portion of the letter to your son/daughter and have them return it tomorrow to Mr. _____, it is very important that I receive your answer.

Thank you for your time and willingness to consider this research project and all it has to offer to your son/daughter.

☐ Yes, my son/daughter can participate in this research study
☐ No, I would prefer if my son/daughter would not participate

________________________________________
Son/Daughter Name

________________________________________
Parent/Guardian Signature

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February 1, 2000

Dear Student,

My name is Chris Merrill and I am a Doctoral Candidate at The Ohio State University in Columbus, Ohio and a 1987 graduate of _____ High School. The reason for this letter is to request your participation in an activity on energy and power technology that will be taught in your industrial/technology classes by Mr. _____ this February. The activity in which I am seeking your participation is centered on real-world, hands-on applications of mathematics, science, and technology education. I am seeking every student who currently has one or more of Mr. _____ classes to voluntarily participate in this activity in order to learn more about how teachers and students interact and how mathematics, science, and technology education are all related. This activity should last no longer than two weeks and is strictly voluntary; you could stop participating at any time. Upon completion of this activity, I will donate a $3,000 piece of equipment called an Energy Bike. The Energy Bike is a classroom tool that allows students to pedal in order to create electricity. This electricity in turn can run fans, hair dryers, radios, and even heat up a liquid.

This activity would require you to answer a series of questions on several different occasions, but would not require any homework or studying by you. You only need to attend class and participate in order to complete the activity.

On the following page there are two choices of participation and two lines in which your printed name and signature should appear. The first box indicates you would be willing to participate and the second box indicates you would not be willing to participate. If you decide not to participate, Mr. _____ will provide you with alternative teaching and learning lessons. Regardless of your choice to participate, you need to print and sign your name. Please take this letter home, discuss it with your parent/guardian, and return it to Mr. _____ tomorrow.
Thank you for your time and consideration.

Sincerely.

Chris Merrill  
Doctoral Candidate  
The Ohio State University

Michael L. Scott, Ph.D.  
Research Advisor  
The Ohio State University

☐ Yes. I would be willing to participate

☐ No, I would rather not participate

__________________________________________  
(Print Name)

__________________________________________  
(Signature)
December 22, 1999

Mr. _____
____ High School
____ Road
____. Ohio _____

Dear Mr. _____,

The purpose of this letter is to request your assistance in a dissertation research study in the field of technology education, entitled “Effects of Integrated Technology, Mathematics, and Science Education on Secondary Technology Education Teachers and Students” at The Ohio State University. You have been selected as an expert panelist based upon your expertise in the field. Specifically, we would like your assistance in evaluating the enclosed research instrument to help us establish validity. This activity should only take about twenty minutes of your time.

The enclosed instrument consists of 100 questions: 63 forced-choice questions and 27 open-ended questions. The research instrument has been developed for ninth through twelfth grade students with varying cognitive levels and abilities. The research instrument questions were developed using Bloom’s Taxonomy of Educational Objectives, i.e., knowledge, comprehension, application, analysis, synthesis, and evaluation. The final version of this research instrument will be utilized by high school students enrolled in technology education in a small suburban village in the United States.

Using the research instrument and the validity checklist, please read and critique the research instrument directions and questions by writing your responses directly on the instrument and validity checklist. Since the instrument is targeted for high school students, we are particularly interested in the extent to which the item measures what it is supposed to (content validity). In addition, please comment on the layout, graphics, and format. You may also add any questions you may think are useful or provide any additional comments you feel necessary.

Please return the research instrument and validity checklist in the enclosed envelope no later than January 17, 2000. Enclosed you will find a monetary reward for your assistance. Your specific responses will not be placed in the final version of this dissertation research, but your name will appear in the “Panel of Experts” appendix, to
acknowledge your contribution, unless you request otherwise. If you have any questions, please telephone or e-mail Chris Merrill at 614-766-7298 (Home), 614-292-7471 (Work), or Merrill.22@osu.edu.

Thank you in advance for helping validate this research instrument. Your input is greatly appreciated.

Professionally,

Chris Merrill Michael L. Scott, Ph.D.
Doctoral Candidate Research Advisor
The Ohio State University The Ohio State University

Enc.
Validity Checklist

Directions: Please evaluate the research instrument using the items listed below. Please place a √ in the appropriate box for each question. Please feel free to make any necessary comments or add additional questions to the instrument. Again, the purpose for this process is to help establish validity. Validity is defined as the degree to which a research instrument measures what is intended to measure.

1. **Content Validity** – Does the instrument measure its intended content area of energy and power technology in an integrated format?
   - √ Yes
   - □ No

   Additional Comments:

2. **Question Clarity** – Are the questions written clearly, unambiguously, and precisely?
   - √ Yes
   - □ No

   Additional Comments:

3. **Complexity** – Is the instrument difficult to follow or answer?
   - □ Yes
   - □ No

   Additional Comments:
4. **Format** – Is the instrument laid out to insure ease of use?

- Yes
- No

Additional Comments:

5. **Length** – Does the instrument have an appropriate length?

- Yes
- No

Additional Comments:

6. **Biased Items** – Are there any questions that should be omitted from this instrument?

- Yes
- No

Additional Comments:

7. **Appearance** – How does the instrument look? Are the graphics appropriate?

- Yes
- No

Additional Comments: