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ABSTRACT

The purpose of this study was to investigate the effects of the 4MAT instructional system on achievement and attitudes in science. Fifty-four academically gifted sixth grade students in three schools in the Chapel Hill-Carrboro (North Carolina) City Schools were randomly assigned to two groups, a 4MAT group and a Restricted-Textbook group that used only left-hemisphere activities. Both groups were taught a three-hour unit on Newton's First Law of Motion. The dependent variables for investigating the effects on achievement were the overall score and the knowledge and critical thinking subscores on an investigator-made achievement test given at the conclusion of the unit of study. Significant differences favoring the 4MAT group were found for overall achievement and on critical thinking questions. No significant differences were found on knowledge-level questions. The dependent variables for investigating the instructional effect on attitudes were the ratings on unit-specific statements and statements about science in general. Significant differences favoring the 4MAT group were found when analyzing the unit-specific statements. Significant differences favoring the Restricted-Textbook group were found when analyzing the unit-specific statements and when analyzing the statements about science in general. Appendixes include lesson plans for both groups, the attitude inventory, and the achievement test and answer key.(TW)

THE EFFECT OF THE 4MAT SYSTEM ON ACHIEVEMENT AND ATTITUDES IN SCIENCE

by

Patricia Shane Bowers

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fullfillment of the requirements for the degree of Doctor of Philosophy in the School of Education.

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PATRICIA SHANE BOWERS. The Effect of the 4MAT System on Achievement and Attitudes in Science (Under the direction of Dr. Paul B. Hounshell)

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The dependent variables for investigating the effects on achievement were the overall score and the knowledge and critical thinking subscores on an investigator-made achievement test given at the conclusion of the unit of study. Group means were compared using a one-way analysis of variance. Significant differences favoring the 4MAT group were found for overall achievement (F [1,52] = 6.19, $p < .05$) and on critical thinking questions (F [1,52] = 13.07, $p < .001$). No significant differences were found on knowledge-level questions.

The dependent variables for investigating the instructional effect on attitudes were the ratings on unit-specific statements and statements about science in

general. Mean group ratings for each score were compared using a one-way analysis of variance. Significant differences favoring the 4MAT group were found when analyzing the unit-specific statements. Significant differences favoring the Restricted-Textbook group (F [1,52] = 5.33, $p < .05$) were found when analyzing the unit-specific statements. Significant differences favoring the Restricted-Textbook group (F [1,52] = 5.33, $p < .05$) were found when analyzing the statements about science in general.

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CHAPTER I

INTRODUCTION

Historically, it has been the mission of educators to maximize the learning of all students, both at the knowledge level and at the process skills level where higher levels of thinking are involved. Volumes have been written on the subject, and much research has been conducted to determine ways to achieve this idealistic goal of maximal learning. Despite these efforts, no definitive answers as to how to achieve this goal have been derived.

The responsibility to maximize learning, especially in the area of critical thinking, has become especially crucial in today's rapidly changing world. Since the turn of the century, several "waves," to use Alvin Toffler's (1980) term, have passed over the world. The First Wave of the agricultural society was washed over by the Second Wave of the industrial society; this, in turn, was washed over by the Third Wave, the information society. Each successive wave has been radically different from, yet complementary to, the previous ones as it has built upon the strengths of the previous waves. The rapidity with which our world is changing was startlingly pointed out in

Future Shock, Toffler's (1970) earlier analysis of the past, present, and future. In that volume he cited Kenneth Boulding's startling statement about the rapid change in our society about how the present moment is a crucial turning point in human history:

> "...as far as many statistical series related to activities of mankind are concerned, the date that divides human history into two equal parts is well within living memory....The world of today...is as different from the world in which I was born as that world was from Julius Caesar's. I was born in the middle of human history..." (p.13)

The seventeen years that have passed since Toffler cited these words have no doubt moved that statistical midpoint in human activities much closer to the middle of the present century.

Conceptual Framework

We are at a point where the immense accumulation of knowledge created by the information society needs to be channeled most profitably. Shane (1986a), a noted educational futurist, anticipates a Fourth Wave of the microbioelectronic world in which we go a step further and begin to use in various ways and places the information and skills of the information age. Shane (1986b) also says we need to have "educated foresight" as a means to move from the information society to the applied knowledge society of the microbioelectronic era. To stress the need to contend with the mass of information being produced every day, he cites Daniel Bell's prediction that "...the rate at which our information is accumulating is likely to double every two years beginning in 1992." (p.52)

This glut of information accumulation has clear educational and economic implications. The need for change in our schools has been decried in more than one hundred national reports in recent years. Among the spate of calls for educational reform in this decade, science has been cited as one area that needs attention. Hurd (1986) cites a National Academy of Sciences panel that said students completing high school are scientifically and technologically illiterate. He further cites A Nation at Risk, the report of the National Commission on Excellence in Education, as saying "...our students lack the essential knowledge and intellectual skills to assume their civic responsibilities or to realize fully their own adaptive capacities. Thus they threaten the nation's economic 'competitive edge.'" (p.353)

The North Carolina Governor's Task Force on Science and Technology presented similar concerns in its report on Public Education and the Technological Challenge. (Shugart, 1984) It stated that the challenge to our schools comes not so much from failure of the schools as it does from changes at the core of the society which the schools serve and that North Carolina must provide a general and uniform system of education at the highest quality level possible. It further says that, due to accelerating technological change, there will be ten times more jobs in technology that do not even exist today than in any other industry. North Carolina's success in dealing with the changing science and technology scene will depend in large measure on our ability to provide skilled workers in science, technology, and other fields.

The problems associated with knowledge accumulation and what to teach students is especially prominent in the area of science. Hurd (1986) says the sciences have burgeoned such that "...it takes nearly 70,000 different scientific journals to report the results of research in the diverse field of science and technology." (p.354) It is logical to assume that no individual can hope to learn all that is included in these journals and that students who possess increased scientific literacy would be better able to understand and apply the information in these journals and elsewhere. The way in which we help students to deal with the situation may be a critical factor in how prepared they are to take their place in tomorrow's technological world. One way science educators can help to produce students who are scientifically literate is to teach basic science content and the concomitant process skills in the most effective manner possible.

Thinking Skills. One way to facilitate the use of the massive amounts of information we are accumulating is to help students go beyond the knowledge and comprehension levels of Bloom's Taxonomy of Educational Objectives (195) and focus on the higher-level (critical) thinking skills of application, analysis, synthesis, and evaluation. These critical thinking skills, combined with reading, computer, research, mathematics, and other facilitation skills, may help these individuals cope with the overwhelming amounts of information being added to our reservoir of knowledge. Clearly, there is no way in which individuals can learn all there is to know in science or any field; they must learn how to seek out information and then to apply, analyze, synthesize, and evaluate it.

The need to develop critical thinking skills has been declared in numerous studies. Frequently it is assumed that if people can state a law in science, they understand it. This is not necessarily so, as McCloskey, Carmazza, and Green (1980) point out. In their study, university students were asked a simple question, based on Newton's Laws of Motion, to indicate the path a moving object would follow in several different situations. More than half the subjects, including many who had taken physics courses, were unable to apply even the most fundamental principles in mechanics. This study by McCloskey, Carmazza, and Green emphasizes the need for not only being able to state information, but for being able to analyze and apply it as well.

Attitudes. Attitudes affect how people feel about a subject and how they achieve in it. Mager (1968) says the objective of instruction is to influence behavior in the future and that attitude influences the extent to which a student puts knowledge to use at a future time. Further, he says educators should strive to help students develop positive attitudes toward a subject to facilitate remembering.

Krynowsky (1985) wrote an extensive review of the literature related to attitudes and science. He says "One of the major goals or objectives for science education programs is to foster more positive attitudes toward science and the scientific enterprise." (p.1) He also cites nineteen studies that indicate the importance of attitudinal goals in science education, a study showing 17% of papers presented at the 1983 National Association for Research in Science Teaching were related to student attitudes, and a study that located more than 2,000 references to attitudes in science during a ten-year period. The sheer number of articles on the topic indicates the import given by researchers to attitudes toward science, and it follows logically that developing positive attitudes toward science is an important component of the goals of science education.

In summary, the United States and the rest of the world are undergoing an information explosion that is producing large amounts of knowledge. Consequently, it is critical for modern-day students to learn not only a core of basic knowledge in science, but also the process skills that will enable them to search out, apply, analyze, synthesize, and evaluate that basic knowledge. In this way the huge amounts of information being accumulated can be managed and interpreted. To facilitate the task, the educational system needs to capitalize on ways to promote positive attitudes and develop the process skills.

Learning Styles. One area that may hold a great deal of promise in assisting educators involves learning styles and brain hemisphericity. However, the study of learning styles is complicated by the lack of agreement by theoreticians on the basic definition of learning styles. Many researchers have presented their views on the issue, and frequently they have produced instruments to measure learning styles according to their understanding and definition of learning styles. Friedman and Alley (1984) believe that "...it is necessary to translate the enormous volume of literature and the more than 30 different learning styles instruments into a manageable, but at the same time meaningful, body of knowledge." (p.77)

Definitions of learning styles are varied. Included here is a sampling of these definitions to indicate this variety. Kuchinskas (1979) defines cognitive style as the way individuals act, react, and adapt to the environment and states that this term often is used in a global manner as synonymous with learning style, teaching style, and administrative style.

In a summary of learning styles research, the Phi Delta Kappa newsletter, Practical Applications of Research (1980), views learning styles as describing students in terms of the educational conditions under which they are most likely to learn. This newsletter states that these styles emerge from inborn, natural inclinations that include preferred ways of learning and descriptions of personality characteristics that relate to learning.

In the forward to Student Learning Styles and Brain Behavior by the National Association of Secondary School Principals, Keefe (1982) lists three areas of learning in his definition: "Learning styles are cognitive, affective, and physiological traits that characterize how learners typically best learn." Dunn, Dunn, and Price (1984) extend Keefe's ideas to include environmental, emotional, sociological, physical, and psychological aspects of learners and their learning environment.

Cornett (1983) is less specific in her definition: Learning styles are overall patterns giving direction to learning behavior. Gregorc's (1979) view is phenomenologic: learning styles are distinctive and observable behaviors that provide clues about individuals' mediational abilities.

Witken, Oltman, Raskin, and Karp (1971) view cognitive styles as characteristic, self-consistent modes of functioning that are manifested in individuals' perceptual and intellectual activities.

There is no general consensus regarding a definition of learning styl. other than that it has to do with individuals and learning. This undoubtedly accounts for the large number of learning style assessment instruments on the market today; individuals do not agree on how to interpret or measure learning styles, so they produce their own instrument. However, most of the learning style instruments Cornett (1983) reviews contain some aspect of brain hemisphere specialization. Brain hemisphericity appears to be the core around which learning styles assessment has developed either directly or indirectly.

Brain Hemisphericity. While investigation into the function of the two hemispheres of the brain dates back almost 25 centuries to Hippocrates (Hart, 1983; Restak, 1982), most current information about the differential operation of the hemispheres has been delineated in the last 30 years. Through a long series of investigations for which he won a Nobel Prize in 1981, Roger Sperry (1964, 1975) determined that, unlike other mammals, humans have brain hemispheres that are specialized in the way they process informatic . The left hemisphere processes information in a linear, sequential manner, while the right hemisphere processes information in a more holistic, global manner. This information has obvious implications for education because much of what is taught tends to be in a linear, sequential manner.

The 4MAT System. While many researchers have written about various aspects of learning styles and brain hemisphericity and their implications for education, the current literature includes only one instructional system that applies what is known about learning styles and brain functioning--Bernice McCarthy's (1980) 4MAT System.

McCarthy based the learning styles component of her system on the work of David Kolb (1976, 1979). Kolb researched ways in which individuals prefer to perceive and process information. From this research he developed the Learning Styles Inventory (Kolb, 1976), which assesses individuals' learning styles and divides them into one of four types depending on how they prefer to perceive and process information. Type-one learners, the Divergers, prefer to perceive information concretely and process it reflectively; type-two learners, the Assimilators, prefer to perceive abstractly and process reflectively; type-three learners, the Convergers, prefer to perceive abstractly and process actively; type-four learners, the Accommodators, prefer to perceive concretely and process actively. McCarthy used Kolb's four learning styles types in her model but modified them slightly, changing the names and broadening the definition of the four learner types.

The brain hemisphericity component of McCarthy's 4MAT System is based on the initial research of Torrance (and later his associates Reynolds, Riegel, and Ball) that resulted in an instrument called Your Style of Learning and Thinking. (1977) Their instrument measures the degree to which individuals process information with either the right or left hemisphere or in an integrated manner, utilizing both hemispheres simultaneously. Although both hemispheres are used, the degree to which individuals rely on one hemisphere or the other for processing information forms a continuum from primarily right-hemisphere processing at one end to primarily left-hemisphere processing at the other end.

McCarthy's system is an eight-step method incorporating Kolb's four learning styles and right and left hemisphere processing. Each step is directed toward one of the learning styles and activities that utilize either the right or the left hemisphere for processing information. In using this system, individuals have an opportunity to learn 25% of the time in their preferred mode; the other 75% of the time they are strengthening the less preferred modes.

Statement of the Problem

Educators must help students acquire a basic core of knowledge in various subject areas, the critical thinking skills with which to apply knowledge in a given situation, and the components that join knowledge and critical thinking such as reading, writing, mathematics, research, and computer skills. The 4MAT System is an educational system that may well hold promise in helping students learn in the most efficient manner possible. However, with only one reported research study on the topic (Wilkerson, 1986/1987), the efficacy of this teaching method is difficult to assess. Because of this dearth of research information, it is important to investigate further the potential of this system to maximize learning.

Three major research questions form the basis of this study: 1) Do students taught Newton's First Law of Motion using the 4MAT System approach have different overall achievement on an investigator-made achievement instrument than students taught using a restricted-textbook method? 2) Do students taught Newton's First Law of Motion using the

4MAT System approach achieve differently on knowledge questions and critical thinking questions on an investigator-made achievement instrument than students taught using a restricted- textbook approach? 3) Do students taught Newton's First Law of Motion using the 4MAT System approach have different attitudes toward the unit of study and science in general, as measured by an investigator-made attitude scale, than students who are taught using a restricted-textbook method?

Hypotheses

The research hypotheses for this study are:

1) Students taught Newton's First Law of Motion using the 4MAT System approach will perform significantly better on overall achievement on an investigator-made achievement test than students taught using a restricted-textbook approach.

2) Students taught Newton's First law of Motion using the 4MAT System approach will perform significantly better on knowledge questions on an investigator-made achievement test than students taught using a restricted-textbook approach.

3) Students taught Newton's First Law of Motion using the 4MAT System approach will perform significantly better on critical thinking questions on an investigator-made

achievement test than students taught using a restricted-textbook approach.

4) Students taught Newton's First Law of Motion using the 4MAT System approach will rate statements about the unit of study on an investigator-made attitude scale significantly higher than students taught using a restricted-textbook approach.

5) Students taught Newton's First Law of Motion using the 4MAT System approach will rate statements about science in general on an investigator-made attitude scale significantly higher than students taught using a restricted-textbook approach.

Definition of Terms

Students. Fifty-seven (54 white and three black) academically gifted sixth grade students in three public schools in the Chapel Hill-Carrboro (North Carolina) City Schools.

4MAT System. A specified eight-step educational system devised by Bernice McCarthy (1980) that is based on learning styles and hemisphericity research.

Restricted-Textbook Approach. An approach that utilizes strictly left-hemisphere procedures to present the information, activities, and teaching suggestions in Prentice-Hall's text General Science: A Voyage of Discovery.

Unit of Study. The information in the Prentice-Hall text, General Science: A Voyage of Discovery, on Newton's First Law of Motion.

Science in General Questions. Questions about science having no specific reference to the Unit of Study.

Knowledge Questions. Questions at the knowledge and comprehension levels of Bloom's (1956) taxonomy.

Critical Thinking Questions. Questions at the application, analysis, synthesis, or evaluation levels of Bloom's (1956) taxonomy.

Investigator-made Achievement Test. A 60-item multiple-choice, true-false, and choose-the-one-that-doesn't-belong test designed by the investigator to test students' understanding of Newton's First Law of Motion. The total score is a compilation of two subscores, one for knowledge questions and one for critical thinking questions.

Investigator-made Attitude Scale. A ten-item rating scale designed by the investigator to assess students' attitudes toward the unit of study and science in general.

Limitations of this Study

This study is generalizable to populations similar those examined in the current study. With different populations, subject areas, length of study, or instruments, the results might have been different.

CHAPTER II

REVIEW OF THE LITERATURE

Research in brain functioning and its applications, once the esoteric realm of psychiatrists and neurologists, is now a popular topic for educators. This is due, in large measure, to the increased awareness of brain hemisphericity, defined by Reynolds and Torrance (1978) as the tendency for individuals to rely more on one cerebral hemisphere than the other for information processing. Most teachers, administrators, and other practitioners in the field of education have heard about brain dominance, and many are interested in its application to the classroom. As a consequence, many "how-to" books and articles on incorporating aspects of right- and left-hemishpere dominance in teaching have been published. Because of the potential for literally changing education, the nature of brain research and its implications is an important topic for educators.

The adult brain is a relatively small organ, weighing about 1.5 kilograms. Despite its size, it contains billions of neurons that are responsible for the functioning of the brain and the entire human body. Hart (1983) reports that estimates of the number of neurons were originally put at 10 billion, but following additional research, some neuroscientists now use 100 billion as an estimate. He conservatively estimates 30 billion. Whichever figure is used, the large number of neruons is astounding and may account to some extent for the vast complexity of the organ.

The brain's complexity is also explained by Paul MacLean's (1978) triune brain theory. The hierarchical triune brain in humans has evolved in three stages, with each stage retaining the basic features of our ancestral relations to reptiles and early and recent mammals.

The triune brain's stages are the reptilian, the limbic, and the new mammalian. The reptilian brain is the oldest and has developed over the last 200 million years. It is basically involved in the organized expression of basic, nonverbal communication of a ritualistic nature such as establishing territoriality. The limbic, or old mammalian, brain is 60 million years old and, through its strong connection with the hypothalmus, is the site of emotions required for self-preservation and the preservation of species. Finally, the new mammalian brain is about 5 million years old and forms the basis of the rational mind. The new mammalian structure comprises about five-sixths of the brain and consists of the cerebellum, which controls motor activities, and the cerebrum, where virtually all the learning in formal education occurs.

History of Brain Research

The brain, as an organ of the body, has long been discussed, although not always accurately. Aristotle saw it merely as a cooling system for the blood when it left the heart, while the ancient Egyptians thought it was unimportant and didn't even embalm it along with other organs. (Restak, 1982) Hippocrates, nearly 25 centuries ago, was the first to view the brain as the organ of the mind and the first to note the dual nature of its hemispheres. (Hart, 1983; Restak, 1982)

The nature of this cerebral duality remained relatively unknown for centuries. In the 17th century, Descartes stated that the brain acts as a united whole in connecting our perceptual world. His whole-brain theory was the dominant one until the 19th century. (Buffington, 1986) Speculations about the brain and its functions have continued to the present.

Two primary factions developed. One group, led by Franz Gall, a German anatomist, proposed that the various functions of the brain were localized in different parts of the brain and that speech was controlled by the frontal lobes. The other group did not believe particular functions could be localized to specific regions of the brain. (Springer & Deutsch, 1985)

Springer and Deutsch (1985) report that during this time of speculation, Marc Dax, an unknown French country doctor, became curious about his patients with aphasia (the loss of speech following brain damage). In more than 40 patients with aphasia, Dax noted that there was damage to the left cerebral hemisphere of the brain, with no cases of damage to the right hemisphere. He presented his findings in a paper at a medical society meeting, concluding that each half of the brain controls different functions and that speech is controlled by the left half. Unfortunately, the paper aroused no interest, and his findings went unnoticed for many years.

In 1861, the controversy about cerebral localization abated when a young French surgeon, Paul Brocca, performed a post-mortem examination on a patient with aphasia and discovered a lesion in the left frontal lobe. Shortly thereafter a similar procedure yielded identical results. Brocca presented his information to the Society of Anthropology, beginning the acceptance of and interest in cerebral localization of function that continues today. Brocca continued his experiments and was able to determine more precisely the area of the brain involving speech. This area is now called Brocca's area. (Buffington, 1986; Restak, 1982; Springer & Deutsch, 1985)

Progress in mapping the functions of the brain moved slowly. In 1878, John Hughlings Jackson asserted that the human brain consists of two distinctive, but anatomically symmetrical parts, the right and left hemispheres. (Raina, 1979) Not until the work of Roger Sperry were significant advances in cerebral functioning made.

Sperry (1964, 1975) conducted historic brain investigations that eventually won him the 1981 Nobel Prize. In the early 1950's, he began investigating the function of the corpus callosum, a band of more than 200 million nerve fibers connecting the right and left cerebral hemispheres. Sperry performed a commissurotomy, a surgical splitting of the brain, on cats, monkeys, and chimpanzees. Outwardly he found little difference in the behaviors of these animals after surgery. However, with additional testing, he determined that the commissurotomy made it impossible for tasks learned in one hemisphere to be transmitted to the other hemisphere; the task would have to be relearned. In addition, the two hemispheres could be trained to do mutually contradictory tasks with no apparent mental distress associated with these tasks.

Additional insight into the corpus callosum's function came in 1961 when Sperry had his first opportunity to study a human split brain. Phillip Vogel and Joseph Bogen, after hearing of Sperry's work, performed a commissurotomy to try to stop debilitating seizures on a brain-damaged man. After the surgery, the man appeared outwardly normal, and his seizures stopped.

Sperry studied the man and subsequently more than 40 others who had similar surgery following the first success. He found several distinct differences in the patients following surgery that led to the conclusion that, unlike other mammals, the two hemispheres of the brain in humans are specialized for quite different functions. Sperry concluded that "Neural circuits for behavior are definitely grown in, pre-functionally, under genetic control--and with great precision in an enormously complex, pre-programmed, biochemically controlled system." (Sperry, 1975, p.31) Furthermore, "...learning in one hemisphere is usually inaccessible to the other hemisphere if the commissures between the hemispheres are missing." (Sperry, 1964, p.44) The corpus callosum acts as a center through which the two hemispheres communicate with one another.

Because information in one hemisphere of a split brain patient is inaccessible to the other hemisphere, Sperry was in a unique position to study the functioning of each hemisphere. By testing and observing, he determined that

> "...both the left and right hemispheres of the brain have been found to have their own specialized forms of intellect. The left is highly verbal and mathematical, performing with analytic, symbolic, computerlike, sequential logic. The right, by

> contrast, is spatial and mute, performing with a synthetic spatio-perceptual and mechanical kind of information processing that cannot be simulated by computers." (Sperry, 1975, p.31)

Since Sperry's initial work, numerous articles have been written concerning aspects of hemisphericity and education. (See, e.g., Buffington, 1986; Chall & Mirsky, 1979; Cohen, 1973; Fox, 1979; Galin, 1976; Garrett, 1974; Gazzaniga, 1967; Grady & Luecke, 1978; Haglund, 1981; Hunter, 1976; Johnson, 1982, 1985; Kane, 1984; Kane & Kane, 1979; Kraft & Languis, 1977; Levy, 1983, 1985; Marx, 1983; McKean, 1985; Oexle & Zenhausern, 1981; Olson, 1984; Ornstein, 1973; Raina, 1979; Restak, 1979; Rubenzer, 1979; Searleman, 1977; Shannon & Rice, 1983; Sinatra, 1983; and Telzrow, 1981.) Figure 1 represents a summary of hemispheric specializations in information processing as gleaned from this literature.

Hemisphericity and the Classroom

The list of hemispheric specializations makes it apparent that much of what transpires in the traditional classroom is oriented to left-hemisphere dominant individuals. Many experts decry this situation and call for emphasis on both hemispheres in the schools. (See Chall & Mirsky, 1978; Galin, 1976; Garrett, 1974; Grady and

Figure 1

A Summary of

Hemisphere Dominance Specializations

Right Hemisphere	Left Hemisphere
non-verbal	verbal
intuitive	logical
divergent	convergent
pattern-oriented	detail-oriented
literal	symbolic
concrete	abstract
deductive	inductive
perceptual	categorical
field dependent	field independent
holistic	linear/sequential
gestalt	parts
mute	speech
visuospatial	printed words/letters
global	analytic
visual	auditory
motoric (tactile/kinesthetic)	
creative	
musical	
intonational	

Luecke, 1978; Hagland, 1981; Hunter, 1976; Johnson, 1982; Levy, 1983, 1985; Kane, 1984; Kraft, Mitchell, Languis, & Wheatley, 1980; Oexle & Zenhausern, 1981; Ornstein, 1973; Raina, 1979; Reynolds & Torrance, 1978; Rubenzer, 1979; Shannon & Rice, 1983; Sinatra, 1983; Sperry, 1975; and Telzrow, 1981.)

Sperry (1975) said our educational system and society in general discriminate against the right half of the brain. The attention given the right hemisphere is minimal when compared to the training of the left hemisphere. He further welcomes the return of such terms as mental imagery and visual, verbal, and auditory images to the literature on such constructs as cognition and perception, feeling that this brings the conscious mind into the causal sequence in human decision-making.

Raina (1979) states that most education patterns are heavily biased toward left-cerebral functioning and are antithetical to the right hemisphere. He says this overemphasis results in adjustment difficulties and a lopsided education for students because they are not offered the whole-brained education necessary to understand the complex nature of the world and themselves.

Schools have placed a premium on the verbal-numerical areas and eliminated the areas of visualization, imagination, and/or sensory/perceptual abilities, continues Raina. These analytic models

> "...emphasize linear thought processes and discourage intuitivity, analogical and metaphorical thinking. These factors of neural functioning among children have been left to modification by random environmental rather than systematic institutional means. Education which is predominantly abstract, verbal and bookish does not have enough place for raw, concrete, esthetic experience, especially of the subjective happenings inside oneself....except in rare cases creative potential is inhibited, or at least diminished ....As a result of excessive emphasis on intellectualizing, verbalizing, analyzing and conceptualizing processes, 'curriculum' has become equated with mere 'understanding'. This imposes 'neurotogenic limitation' and binds mental processes so tightly that they impede the perception of new data." (p.13)

Problem Solving. Grady and Leucke (1978) suggest the bias for the left hemisphere developed as people grew more and more capable of manipulating their environment. Initially people had to struggle for mere survival and basic needs. The left-hemisphere functions of analysis and sequence yielded superior capabilities in helping people to survive and develop. The supremacy of analytical thought evolved from the need for these skills in survival.

Many of today's problems such as overpopulation, pollution, energy, ecology, and medicine have resulted from these linear thought processes, say Grady and Leucke. Further, solutions to these problems usually are linear, piecemeal answers that solve only parts of problems. Problem solving necessitates the more global approach to situations that the right brain takes.

The enhancement of the problem-solving skills viewpoint is shared by Ornstein (1973), who feels a shift from focusing on the egocentric linear processes to a focus on holistic and simultaneous processes can provide solutions to complex problems.

Galin (1976) promotes the need for right- and left-hemisphere activities to aid problem solving, saying that the holistic mode is very good for creatively bridging gaps. The verbal-analytic style is good for contending with the object world, but it must proceed in a step-by-step, linear fashion. Holistic thinking enables people to look at the entire picture, skipping parts as necessary to arrive at an end point. Thus, developing right-hemisphere abilities can help them to see the global picture and to make the nonsequential mental leaps so often necessary in problem solving.

Achievement Enhancement. In light of split-brain research and current curricular trends, Grady and Luecke

(1978) advocate that schools should evaluate their curricula and instructional practices to balance the functions performed by the left and right hemispheres. Educators need to develop systematic and sophisticated curricula that will facilitate the brain's multiple processing systems. Adding subjects that require right-hemisphere stimulation can provide not only stimulation for right hemisphere growth, but also content integration needed for a balanced curriculum.

This balanced curriculum has been shown to increase overall performance on standardized tests. Grady and Leucke (1978) cite a 25-member panel reporting in a two-year survey, Coming to Our Senses: The Significance of the Arts for American Education, that reported three programs showing increased test scores. In the first study, students in one school who participated in the "Learn To Read Through The Arts" balanced-curriculum program showed significant gains in reading scores.

The second study showed that students who attended art classes six to eight times more often than students normally do scored significantly higher on standardized reading and math tests than those who attended art class less frequently.

The third study, the "Interdisciplinary Model Program in the Arts for Children and Teachers," reported that students participating in the study gained in reading and math ability and showed superior problem-solving ability.

An increase in learning as a result of increased right-hemisphere education is also cited by Hagland. (1981) She reports that stimulation of both sides of the brain may produce more effective learning. She also says that a hardship may be imposed on right-hemisphere individuals whose strengths lie in imagery or spatial relationships. Education for these individuals relies on language processing being presented through several combined approaches, including exposure to a variety of concrete objects and sensory experiences when first learning to read. Overemphasis on abstract symbols represents educational irresponsibility due to underdevelopment of right-hemisphere capacities. She adds that "This is not simply a matter of enrichment, but one of rescuing neglected potential important for high level problem solving along with proficiency with language skills." (p.231)

A study that involved a high level of hands-on science in the elementary classroom also supports the halo effect of the right hemisphere instruction enhancing achievement in left-hemisphere areas. When a right-hemisphere approach with a heavy emphasis on active involvement in hands-on science was utilized in an elementary school, reading scores improved significantly. The investigator speculates that the concrete experiences provided for cognitive stimulation that affected learning across hemisphere lines. (Rowe, 1975)

The research of Jean Piaget (1975) and the need for developing schemata based on concrete experiences is related to hemisphericity, says Sinatra (1983). He says schemata are representations of life's experiences that become the child's basis for a conceptual filing system. The younger the child, the more likely that language experiences will be based on concrete happenings. He concludes that right-hemisphere stimulation up through primary grade schooling may be the cornerstone for success with verbal modes in later grades.

Sinatra explains that myelination is the process of nerve maturation whereby a fatty sheath (mylin) that facilitates neuron transmission develops around nerves. The nerve fibers of the corpus callosum connecting the right and left hemispheres of the brain are the last to myelinate during childhood. There appears to be a correlation between myelination and the maturation of the cognitive powers. Because of this, preschoolers and primary grade students whose myelination is not complete are physiologically unable to perform tasks requiring integration of the hemispheres. Because visuospatial, manipulative activities stimulate myelin growth, nonverbal-verbal hemispheric integration can be advanced by employing these right-hemisphere activities. Sinatra says the research implications are that interhemispheric integration is facilitated when right-hemisphere techniques are employed. Consequently, he advocates visual/motor activities as a regular ingredient in the curriculum.

Other Influences on Hemisphericity. While the tendency to process information in one hemisphere or the other is genetically influenced (Sperry, 1975), enculturation can affect information processing in the cerebral hemispheres. Investigators have reported that middle class persons are likely to exhibit greater tendency to use the verbal-analytic mode while the urban poor are more likely to use the spatial-holistic mode. (Cohen, 1969; Lesser, 1971) Cohen also found that poor children had a tendency to be relational thinkers who tend to give attention to global aspects of a stimulus. She suggests that curricular integration of both cognitive modes may be able to stimulate creative achievement in some failing students.

Attention and Hemisphericity. Because many students are not verbal learners, they may be missing much of what transpires in the classroom where a great deal of information is transmitted via the lecture method. Instruction that utilizes both hemispheres does not rely exclusively on this method of instruction.

Restak (1979) and Johnson (1985) describe the interaction of and interdependence of Soviet neurophysiologist Alexander Luria's three brain systems: the attentional, the sensory, and the intentional systems. Johnson relates some physiologic aspects of the dangers of excessive verbal instruction to these three systems of the brain. Each system acts independently, and brain activation plays a different role with each of these systems. Attention to the way in which individuals perceive information is thus an essential part of these systems.

Johnson (1985) relates Luria's systems to education. Like MacLean's (1978) limbic system, the attentional system is strongly associated with emotions and controls tone, alertness, and the waking state. A series of two-way "gates" regulates information coming to this system; if the system perceives incoming stimuli as nonrelevant, dull, or threatening, it closes the "gates," and the hippocampus, which is involved in long-term memory, cannot be activated. Instruction that utilizes both hemispheres, and therefore appeals to both preferences for information processing, is more likely to be relevant and nonthreatening to learners. Consequently, it is important to make information relevant so it is more likely to keep the "gates" to long-term memory open.

Luria's sensory system has sensory areas in the right and left hemispheres. This system is directly related to cerebral lateralization in that each hemisphere is sensitive to different forms of stimuli--the left responding to verbal, sequential, and time-related material, and the right responding to spatial relationships, melody, pictorial, and nonfamiliar stimuli.

The critical component of the sensory system is that neurons, when properly stimulated, form more receptors for synapses (the point at which the nervous impulse passes from one neruon to another), thus increasing neural connections. Since the number of neurons in the brain is static, this is the only way the neurons can grow; increased stimulation provides for increased growth. Thus, it is important to stimulate both parts of the sensory system for brain growth.

Finally, in the intentional system, the brain grows only when the neurons are stimulated and the cells themselves grow. The frontal lobe will develop only with this stimulation. The cognitive strategies required for Piaget's (1975) formal reasoning stage resemble those required for development of the intentional system. This system needs to be activated so that the right hemisphere can hold the images of what it is learning long enough for the left hemisphere to transform them into an accurate abstract representation and is then able to "talk" about it.

The 4MAT System

Bernice McCarthy (1980) has presented a model for teaching, the 4MAT System. This system is based on research in learning styles and brain hemisphericity as well as creativity, effective management, art, and movement and dance.

McCarthy was intrigued by the similarities of the work of eighteen researchers in various areas, including learning styles and brain hemisphericity. She was equally interested in the implications of their research for education. She convened a conference in 1979 to discuss the dynamics of the interrelationships among these researchers. It was from this conference that the 4MAT System grew.

4MAT and Learning Styles. In her text, McCarthy (1980) discusses how the commonalities in the learning styles research of Barbara and Louis Fischer, Anthony Gregorc, Karl Jung, David Kolb, Alex Lotas, David Merrill, and Elizabeth Wetzig influenced her in the development of her 4MAT System. Although her model reflects the work of all these authors, it is based on the research of Kolb.

David Kolb (1975, 1979) researched experiential learning and its relationship to cognitive development. He formulated a model that designated learners in terms of how they perceive and process information; one's learning style is a composite of these two dimensions. The first dimension forms a dichotomy on two ends of a continuum in terms of how people prefer to perceive information: Concrete Experience and Abstract Conceptualization. Individuals who prefer to perceive concretely like to immerse themselves in concrete reality and become totally involved in the learning process. In contrast, individuals who prefer to perceive abstractly like to look at a situation and contend with it on an abstract level by thinking about it.

In a similar vein, the second dimension also forms a bipolar continuum in terms of the way individuals prefer to process the information they have perceived: Active Experimentation and Reflective Observation. The active processors are doers who like to be actively involved in the learning process; in contrast, the reflective processors prefer to sit back and observe what is happening as they learn.

Kolb divides learners into four categories depending on their particular combination of ways they perceive and process information. The first type, Divergers, prefer to perceive information concretely and process it reflectively. The second type, Assimilators, prefer to perceive information abstractly and process it reflectively. The third type, Convergers, prefer to perceive information abstractly and process it actively. Finally, the fourth type, Accommodators, prefer to perceive information concretely and process it actively. Kolb developed the Learning Style Inventory (1976) to assess the learning style of individuals.

McCarthy (1980) used Kolb's model as the basis for the learning styles component in her 4MAT System. She changed the names Kolb used, but her system remains faithful to his model. She calls the type one learners Innovative Learners, type two Analytic Learners, type three Common Sense Learners, and type four Dynamic learners.

4MAT and Brain Hemisphericity. After studying learning styles, McCarthy became interested in what relationship, if any, existed between learning style and brain hemisphericity. Using Kolb's Learning Style Inventory (1976) and Paul Torrance's test, Your Style of Thinking and Learning, Form B, (1978) McCarthy tested 329 high school students. She found that approximately equal percentages of each gender fell into each of the four learning style groups. Sixty percent of the students fell into the Concrete Experience end of the Concrete-Abstract perception continuum, while the processing continuum had 57% being Reflective and 43% being Active. She also found that 46% of the students were right-hemisphere dominant, while 28% were left-hemisphere dominant and 25% were integrated-dominant.

McCarthy found that all three types of brain dominance were represented in all four learning styles, but only the Analytic Learners had a higher percentage of left-hemisphere dominant members than any other type of brain dominance. In addition, Innovative Learners and Common Sense Learners tended to have more integrated dominance than do the Analytic Learners and Dynamic Learners. Finally, she found that gender has some relationship to integrated dominance, with 33% of the females and only 15% of the males being integrated-dominant.

McCarthy thus determined that there may, indeed, be a relationship between learning styles and brain hemisphericity. Individuals fall into four learning styles, and within each learning style, they exhibit right-, left-, or integrated-hemisphere processing. Based on this information, she developed her 4MAT System for instruction, an eight-step cycle incorporating Kolb's four learning styles as well as right- and left-hemisphere processing within each learning-style quadrant.

McCarthy's model describes learners and the ways they are taught within the framework of the model using nine categories: 1) the type of learners, 2) how the learners prefer to perceive information, 3) the type of question learners ask themselves, 4) the kind of learning concerns the individuals have, 5) the strengths the learners have,

6) the processes the learners in a particular quadrant use, 7) the teacher's role within each quadrant, 8) the teaching method used within each quadrant, and 9) the purpose for the hemispheric experience within each quadrant. These categories are summarized in Figure 2.

McCarthy feels Kolb's model is important not only because it provides a way to categorize learning styles, but also because of the sequence of learning his model encompasses: a cycle of instruction that involves experience, reflection, conceptualization, and experimentation. In this way, all students are taught in their preferred learning style 25% of the time and have an opportunity to expand their abilities in the other learning styles the rest of the time. She further says this is important because if they are not exposed to a variety of learning styles they will not develop other learning skills.

4MAT Research. Little research has focused on McCarthy's 4MAT System. A review of the literature revealed only one research study. Wilkerson (1986/1987) evaluated the effects of the 4MAT System on third graders' 1) academic achievement, 2) retention of learning, and 3) attitudes toward the unit of instruction and science in general. The control group was taught using a traditional, textbook approach. Using Bloom's (1956) taxonomy to

Figure 2

A Summary of

McCarthy's 4MAT System

	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
type learner	innovative	analytic	common sense	dynamic
prefers to	perceive concretely, process reflectively	perceive abstractly, process reflectively	perceive abstractly, process actively	perceive concretely, process actively
question	WHY do I need to learn this?	WHAT are the facts?	HOW does this work?	IF...how can I apply this?
individual has concern for	personal meaning: give them a reason	facts: teach it to them	hands-on experience: let them try it	action, doing: let them teach & share
strengths	innovation & ideas, brainstorming, listening, interacting, speaking	creating concepts & ideas, observing, classifying, drawing conclusions, seriating	practical application, experimenting, manipulating, following directions	action; getting things done; applying, testing w/reality; carrying through
function by	values clarification	thinking things through	factual data garnered from kinesthetic experiences	acting and testing experiences
teacher's role	motivator, witness	information-giver	coach	evaluator, remediator
method	discussion, interaction	informational	facilitation, organizational	self-discovery
purpose	right create an experience	right integrate observation/ reflective	left practice defined givens	right think about application for relevance
	left reflect/ analyze experience	left develop theories, concepts, & skills	right practice, adding something of yourself	left share what you've done with others

classify test questions, she found significant differences favoring the 4MAT group, $p < .05$, on achievement classified as knowledge, comprehension, application, and analysis, and on retention after 35 days; but she found no significant differences between the groups on achievement classified as synthesis and evaluation. In addition, she found students' interest in science and attitudes toward the instructional activities were more positive with the 4MAT group than with the control group.

CHAPTER III

METHODOLOGY

The purpose of this study was to investigate the effects of the 4MAT instructional system on achievement and on attitudes toward the unit of study and science in general.

There were two instruments used in this study. The achievement test assessed achievement at two levels derived from Bloom's (1956) Taxonomy of Educational Objectives: knowledge and comprehension and critical thinking (application, analysis, synthesis, and evaluation). The attitude measure assessed attitudes about the unit of study and about science in general.

The research design was a Posttest-Only Control Group experimental design (Campbell & Stanley, 1963). One-way analysis of variance was used to determine if there were significant differences between groups. The dependent variables were the two subscores and the total score on the achievement instrument and the two subscores on the attitude instrument. The independent variable was the group into which students were assigned.

Subjects

Fifty-four students (three black and fifty-one white) in academically gifted sixth grade classes in three schools in the Chapel Hill-Carrboro (North Carolina) City Schools participated in this study. These students were chosen because their teachers had participated in a ten-hour staff development workshop on Newtonian Mechanics the previous autumn and thus had a common subject matter background. The investigator also participated in the workshop. The investigator felt this common background was important to avoid the skewed results that might develop if one teacher had a more extensive subject matter background than the other teachers.

A letter outlining the purpose of the study and guaranteeing anonymity was sent home to parents a month before the study began. Students were told they could drop out of the study at any time, and there would be no penalty for those who chose not to participate. Fifty-eight students were enrolled in these classes; two students opted not to participate, and two had to be dropped from the study because of absences. Fifty-four students completed the study, with twenty-seven each in the experimental and control groups.

Design

Treatment. The treatment variable for this experiment was two methods of instruction for teaching a unit on Newton's First Law of Motion. One method of instruction was a restricted-textbook approach that involved teacher lecture, reading of text materials, writing activity sheets, and completing two activities. This approach was restricted to activities that represent left-hemisphere specializations that are verbal, logical, abstract, and linear/sequential in nature.

The other method was Bernice McCarthy's (1980) 4MAT System approach utilizing a sequence of instruction taking into account specific learning stvles as well as right- and left-hemisphere dominance.

The teachers at each school were females certified in Academically Gifted education. The investigator was certified in Middle Grades Science. Each of the teachers and the investigator had at least ten years of teaching experience.

Assignment to Treatment Group. The students in each school were randomly assigned to either the experimental or control group using a table of random numbers. The assignment was done in the following manner. For each class, the investigator arbitrarily selected a spot to begin looking at the numbers in a table of random numbers. She looked down the column until she came to the first number that was assigned to a student. If the first number chosen was even, that individual was assigned to the control group; if it was odd, that individual was assigned to the experimental group. The investigator continued from the same point in the table of random numbers until she came to the next number that had been assigned to a student. That student was placed in the opposite group. This method was followed until all students were placed in one of the two groups.

Teacher Assignment. The academically-gifted teachers shared the teaching of the experimental unit with the investigator. The teachers and the investigator alternated the days they taught each group to provide for instructional counterbalancing. Alternating the rooms where the students met counterbalanced the effect of the classroom.

The decision as to which group each instructor would begin teaching was made separately for each school by assigning the teachers even numbers and the investigator odd numbers. If, from a table of random numbers, the first number selected was even, the teacher began with the control group, and the investigator began with the experimental group. If the first number selected was odd, the investigator began with the experimental group, and the teacher began with the control group.

Procedure

Length of Treatment. The experiment was conducted during the last week in April and the first week in May, 1987. Each class met for a total of three hours. Two of the groups met four days for forty-five minutes each day. Due to the class schedule, the other group met three days for one hour. Within each school, the students were randomly divided, and the length of instruction was equal. Thus, all students within each school were treated the same.

Before treatment began, each teacher completed an Assessment of Class Form (Appendix D) to document any differences among students in the classes that might affect the results. This was completed before the teachers knew which students were in the experimental group and which were in the control group to prevent any potential bias.

The attitude measure (Appendix E) and the achievement test (Appendix F) were given the day after the end of the experiment.

Subject Matter. Both groups were taught Newton's First Law of Motion using the same terminal objectives. (Appendix A) Instructional packets were designed for each group. These packets included lesson plans with a script to ensure uniformity of instruction, information sheets for the students, activities to use in instruction, and materials to complete the activities. (Appendices B and C) The terminal objectives were drawn from the information in the Prentice-Hall textbook. Care was taken to ensure that the content in the 4MAT information sheets was the same as that in the textbook.

The information sheets and activities for the control group were the sections in Unit 6, Chapters 1 and 2 of Prentice-Hall's General Science, A Voyage of Discovery (Hurd et al., 1986), that pertain to the First Law of Motion. This book was selected because it is recent, gives coverage of the Laws of Motion, and is written for grades six through nine. The lesson plans used teaching strategies and activities suggested in the Prentice-Hall book. The word-scramble puzzle used is a modification of the puzzle presented in the teacher's resource book.

The content information sheets used by the experimental group were written by the investigator. The information in these sheets was selected so it would cover the same topics in the Prentice-Hall book. The activities were those developed by Gartrell (1986) and an investigator-made crossword puzzle. The Gartrell materials were the same as those used in the workshop on Newtonian Mechanics that the teachers and the investigator had completed earlier.

The content validity of the 4MAT materials was established as follows. A current middle grades physical science teacher and a former middle grades physical science teacher (who also was the instructor at the Newtonian Mechanics Workshop the three teachers and the investigator attended) read the 4MAT script and information sheets and verified the accuracy of the concepts presented. In a similar manner, two other middle grades teachers reviewed the textbook lesson plans, compared them with the textbook and accompanying teachers' guide, and verified that the lessons accurately represented the text and teaching suggestions. (Appendix G)

McCarthy is very specific about the order in which each learning styles quadrant, and the hemispheric modes within each quadrant, are to be taught. To ensure that the 4MAT lessons developed were valid representations of the 4MAT System, two people certified by 4MAT as trainers reviewed and validated the 4MAT script as accurately representing the 4MAT System. This was done in the following manner. The activities in the 4MAT lesson plans were written in random order. The reviewers were asked to determine to which of the eight steps each of the activities belonged. The reviewers matched the steps to each of the eight steps the investigator had determined with 100% accuracy. These two individuals also reviewed the activities for the restricted-textbook instructional packet, again in scrambled order, and verified that the activities included there were all left-hemisphere activities. (Appendix G)

Monitoring Treatment Delivery. The investigator monitored the treatment in two ways. First, tape-recorded lessons presented by the teachers were reviewed each day of treatment. In this way, any deviations from the script could be noted, and the investigator could discuss the deviation, if necessary, with the individual teacher involved. Second, the teachers were interviewed following each lesson to identify any problems.

Instrumentation. Two instruments were administered to the subjects. The first was an investigator-constructed achievement test on Newton's First Law of Motion. (Appendix F) The questions were derived from a variety of sources including the study by McCloskey, Carmazza, and Green (1980), the Prentice-Hall teachers' resource book (Hurd, et al., 1986), Gartrell's (1986) activities, as well some written by the investigator.

Using Bloom's (1956) Taxonomy of Educational Objectives as the criteria, the sixty-item test was divided into thirty-five knowledge questions (numbers 1, 2, 12-14, 17-26, 28-30, and 38-54) and twenty-five critical thinking questions (numbers 3-11, 15, 16, 27, 31-37, and 55-60). Two professors at the University of North Carolina at Chapel Hill who teach learning theory courses reviewed the achievement test and, using the Bloom taxonomy, rated each question as being either a knowledge or a critical thinking question. There was 100% agreement as to which questions belonged to which category.

The reliability of the achievement instrument was determined by field-testing it with a group of twenty-five heterogeneous sixth grade students who had recently completed a unit on Newtonian mechanics using materials from the workshop the three teachers and the investigator in this study had attended. The test had a Kuder-Richardson-20 reliability of .84. Through an item analysis, those items with difficulty index of <.30 or >.85, negative correlations, or correlations = or < .00 were dropped, leaving sixty of the original eighty questions in the final version of the test. Only the students in the study took the final version of the test. For this version of the test, the Kuder-Richardson-20 reliability was .83.

The achievement test was constructed to assess the content covered in both the control and experimental groups. Two middle grades teachers who took the Newtonian Mechanics Workshop and who have extensive backgrounds in science reviewed the questions to determine if they accurately represented the stated objectives for the unit. There was 100% agreement that the items were appropriate. (Appendix G)

The second instrument was an investigator-constructed Attitude Survey. (Appendix E) The attitude statements were designed to determine (1) how well the students liked the unit they had just completed and (2) their attitudes toward science in general.

The ten questions on this instrument were divided into two parts, those that referred specifically to the unit of study (numbers 1-4, 6, and 10) and those having to do with science in general (numbers 5, 7, 8, and 9). The reliability of the Attitude Survey was determined by using a Cronbach's Alpha reliability test on the attitude measure. Only the students in the experiment completed this instrument. The reliability for the instrument was .79.

The Attitude Survey was field-tested with a group of academically gifted fifth grade students who had completed a similar unit on Newtonian mechanics to ensure that the questions on the survey were easily understandable. The students reported that they had had no difficulty in understanding the questions.

Statistical Analysis. Raw achievement test and attitude survey scores were used to determine descriptive statistics (range, mean, variance, and standard deviation) for the two groups. The achievement test had two subscores (knowledge and critical thinking questions) as well as a total achievement score. The Attitude Survey had two subscores, unit-specific statements and statements about science in general.

Separate one-way analysis of variance was used to determine if there were statistical differences between the experimental and control groups on the total scores on the achievement test and the two subscores on the achievement and attitude instruments.

CHAPTER IV

RESULTS

This study investigated the effects of using the 4MAT instructional system on achievement, knowledge- and critical thinking-level questions, and on attitudes toward both the unit of study and toward science in general. Academically gifted sixth grade students were the subjects for this study. The unit of instruction was Newton's First Law of Motion.

The data for this study were derived from the results of an investigator-made achievement test and an investigator-made attitude inventory. The investigator-made achievement test consisted of two subparts: knowledge questions [at the knowledge and comprehension levels of Bloom's (1956) taxonomy] and critical thinking questions (at the application, analysis, synthesis, and evaluation levels of Bloom's taxonomy). The investigator-made attitude inventory consisted of questions specifically related to the unit of study and questions relating to science in general.

The Relationship Between Achievement and Instructional Approach

The first three hypotheses investigated overall achievement and achievement on knowledge questions and critical thinking questions of students taught using the 4MAT System approach and students taught using a restricted-textbook method utilizing only left-hemisphere instruction. Overall achievement results were analyzed using a one-way analysis of variance. The two subscores on the overall achievement instrument for knowledge and critical thinking questions also were tested using analysis of variance.

Hypothesis 1. The null hypothesis was: There is no significant difference in overall achievement on an investigator-made achievement test between a group of students taught using the 4MAT System approach and a group of students taught using a restricted-textbook approach.

The research hypothesis was: Students taught Newton's First Law of Motion using the 4MAT System approach will perform significantly better on overall achievement on an investigator-made achievement test than students taught using a restricted-textbook approach.

The analysis of variance indicated that there was a significant difference in overall mean achievement between the two groups in favor of the group using the 4MAT System (F [1,52] = 6.19, p < .05). The null hypothesis was rejected, and the research hypothesis was supported. Table 1 presents the descriptive statistics for the overall achievement test scores. Table 2 presents a summary of the analysis of variance.

Table 1

Descriptive Statistics for the Test of Overall Achievement

	N	# Questions	Mean	S.D.	Range
4MAT Group	27	60	43.85	6.92	21-56
Restricted-Textbook Approach	27	60	38.93	7.35	22-50

Table 2

Summary Table of ANOVA for the

Test of Overall Achievement

Source	SS	df	MS	F
Between Groups	327.58	1	327.58	6.19*
Within Groups	2751.26	52	52.91	
Total	3078.84	53		

* $p < .05$

<u>Hypothesis 2</u>. The null hypothesis was: There is no significant difference on knowledge questions on an investigator-made achievement test between a group of students taught using the 4MAT System approach and a group of students taught using a restricted-textbook approach.

The research hypothesis was: Students taught Newton's First Law of Motion using the 4MAT System approach will perform significantly better on knowledge questions on an investigator-made achievement test than students taught using a restricted-textbook approach.

The analysis of variance indicated that there was no significant difference in mean achievement on knowledge questions between the two groups (F [1,52] = 1.72, p > .05). Consequently, the null hypothesis cannot be rejected. Table 3 presents the descriptive statistics for the scores on the knowledge questions on the achievement test. Table 4 presents a summary of the analysis of variance.

Table 3

Descriptive Statistics for the Knowledge Questions on the Test of Overall Achievement

	N	# Questions	Mean	S.D.	Range
4Mat Group	27	35	27.78	4.64	13-33
Restricted-Textbook Group	27	35	26.19	4.28	17-31

Table 4

Summary Table of the ANOVA for the Knowledge Questions on the Test of Overall Achievement

Source	SS	df	MS	F
Between Groups	34.24	1	34.24	1.72
Within Groups	1034.74	52	19.90	
Total	1068.98	53		

Hypothesis 3. The null hypothesis was: There is no significant difference on critical thinking questions on an investigator-made achievement test, between a group of students taught using the 4MAT System approach and a group of students taught using a restricted-textbook approach.

The research hypothesis was: Students taught Newton's First Law of Motion using the 4MAT System approach will perform significantly better on critical thinking questions on an investigator-made achievement test than students taught using a restricted-textbook approach.

The analysis of variance indicated that there was a significant difference in the means for the critical thinking questions between the two groups favoring the group using the 4MAT System (F = 13.07, p < .001). The null hypothesis was rejected, and the research hypothesis was supported. Table 5 presents the means and standard deviations for the questions on an overall achievement test. Table 6 presents a summary of the analysis of variance.

Table 5

Descriptive Statistics for the
Critical Thinking Questions on the
Test of Overall Achievement

	N	# Questions	Mean	S.D.	Range
4MAT Group	27	25	16.11	3.65	9-23
Restricted-Textbook Group	27	25	12.59	3.50	5-19

Table 6

Summary Table for the ANOVA for the Critical Thinking Questions on the Test of Overall Achievement

Source	SS	df	MS	F
Between Groups	167.13	1	167.12	13.07*
Within Groups	665.19	52	12.79	
Total	832.32	53		

* p < .001

The Relationship Between Attitudes and Instructional Approach

The fourth and fifth hypotheses tested the attitudes toward the specific unit of study and science in general of students taught using the 4MAT System approach and students taught using a restricted-textbook method utilizing only left-hemisphere activities. The two subscores on the attitude inventory for unit-specific questions and questions about science in general were tested using analyses of variance.

Hypothesis 4. The null hypothesis was: There is no significant difference in attitudes toward the unit of study, as measured by an investigator-made attitude inventory, between students taught using the 4MAT System approach and students taught using a restricted-textbook approach.

The research hypothesis was: Students taught Newton's First Law of Motion using the 4MAT System approach will rate statements about the unit of study on an investigator-made attitude scale significantly higher than students taught using a restricted-textbook approach.

The analysis of variance indicated that there was a significant difference between the means of the two groups favoring the 4MAT System approach group over the restricted textbook group (F [1,52] = 5.33, $p < .05$). The null hypothesis was rejected, and the research hypothesis was supported. Table 7 presents the means, standard deviations, and ranges for the attitude questions relating specifically to the unit of study. Table 8 presents a summary of the analysis of variance.

Table 7

Descriptive Statistics for the Attitude Statements About the Unit of Study

	N	# Questions	Means	S.D.
4MAT Group	27	6	15.59	3.50
Restricted-Textbook Group	27	6	13.48	3.22

Table 8

Summary of ANOVA for the Attitude Statements About the Unit of Study

Source	SS	df	MS	F
Between Groups	60.17	1	60.17	5.33*
Within Groups	587.26	52	11.29	
Total	647.43	53		

* $p < .05$

Hypothesis 5. The null hypothesis was: There is no significant difference in general attitude toward science, as measured by an investigator-made attitude inventory, between students taught using the 4MAT System approach and students taught using a restricted-textbook approach.

The research hypothesis was: Students taught Newton's First Law of Motion using the 4MAT System will rate statements about science in general on an investigator-made attitude scale significantly higher than students taught using a restricted-textbook approach.

The analysis of variance indicated that there was a significant difference between the means of the two groups favoring the restricted-textbook group (F [1,52] = 5.20, p < .05). The null hypothesis was rejected. However, the research hypothesis was not supported because the results were in the opposite direction from those predicted in the research hypothesis. Table 9 presents the descriptive statistics for the general attitude toward science scores. Table 10 presents a summary of the analysis of variance.

Table 9

Descriptive Statistics for the

Attitude Statements About Science in General

	N	# Questions	Means	S.D.
4MAT Group	27	4	11.48	2.38
Restricted-Textbook Group	27	4	13.33	3.49

Table 10

Summary of ANOVA for the

Attitude Statements About Science in General

Source	SS	df	MS	F
Between Groups	46.30	1	46.30	5.33*
Within Groups	462.74	52	8.90	
Total	509.04	53		

* $p < .05$

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effects of instruction utilizing the 4MAT System on achievement and attitudes of academically gifted sixth grade students. The students received three hours of instruction on Newton's First Law of Motion. Instruction using the The 4MAT System approach (McCarthy, 1980) had components that were congruent with each of the four major learning styles and brain hemisphere dominance. Instruction utilizing a restricted-textbook approach followed the textbook and its teaching suggestions and used only left-hemisphere activities.

Conclusions

The results of the analyses generally support the research hypotheses, which are discussed below.

Achievement. The first three research hypotheses concerned instructional approach and achievement.

Hypothesis 1 concerned the difference in overall achievement on an investigator-made achievement test between students taught using the 4MAT System approach and students taught using a restricted-textbook approach. The results of the one-way analysis of variance support the research hypothesis that there are significant differences between the two groups on overall achievement favoring the 4MAT System approach ($p < .05$).

These results were expected for three reasons. First, the 4MAT System appeals to all four major learning styles as well as to right- and left-hemisphere dominance within each learning styles group. In this way, individuals were taught in their preferred learning style 25% of the time. Individuals who are not usually systematically taught in this fashion were allowed to learn in the way they learn best.

Second, by utilizing a variety of teaching approaches to incorporate the various learning styles and hemisphere dominance, the 4MAT System added variety to the lessons. The combination of addressing learning styles and hemisphere dominance along with the instructional variety that is entailed is likely to have increased the probability that instruction would attract the attention of the students, a necessary condition for activating Luria's Attentional System and long-term memory. (Johnson, 1985)

Third, it was expected that students would be better able to apply the subject matter they had learned when answering questions at the critical thinking level of Bloom's (1956) taxonomy: application, analysis, synthesis, and evaluation. Since critical thinking questions were included as a part of the achievement test, it was expected that the 4MAT System approach group would do better on the overall achievement test.

Hypothesis 2 investigated the relationship between achievement on knowledge questions and instructional group. The research hypothesis was that students in the 4MAT System approach group would achieve significantly higher than those students in the restricted-textbook group. The differences were not statistically significant ($p > .05$), and thus this hypothesis was not supported.

Lack of support for Hypothesis 2 was not expected. It would seem that if the 4MAT System approach engages the learner to a higher degree than the restricted textbook approach (see the discussion of Hypothesis 1), the achievement at all levels should reflect that engagement. It is possible that the lack of significant differences arose because of the nature of the questions. Knowledge-level questions are rote, usually deal with part of the whole, and are frequently linear-sequential in nature, characteristics of left-hemisphere specialization. Because both groups received instruction using left-hemisphere techniques, it is likely that the engagement of the students at this level was the same for both groups.

A second, related explanation may lie in the general instruction the students usually receive. It is possible that because the subjects were academically gifted students, all were capable of accommodating to the system that traditionally tests with knowledge-level questions. Thus, because the students have learned to excel at these types of questions, the differences were more likely to be smaller.

Hypothesis 3 investigated the relationship between achievement on critical thinking questions and membership in instructional group. The research hypothesis that the 4MAT System approach group would achieve higher than the restricted textbook group was supported ($p < .001$).

These results were expected due to a combination of instruction being directed, at least part of the time, to both the individuals' given learning style preferences and hemisphere dominance. In addition, as discussed in Hypothesis 1, the use of a variety of teaching approaches was likely to have activated the learners' attentional systems.

These results were also expected because acquiring the knowledge necessary for success on critical thinking questions was more demanding. In addition to learning the knowledge, the students also had to use the knowledge. The results of Hypothesis 3 indicate that the students in the 4MAT System approach seemed to have a better understanding of the subject matter and were more able to apply the knowledge obtained on critical thinking questions. This suggests that an instructional system that is directed to learning styles and brain dominance develops these abilities to a greater extent.

Finally, explanation for the significant results favoring the 4MAT group may be explained if one considers that problem solving lies in the realm of the right-hemisphere specialization. (Grady and Leucke, 1978; Ornstein, 1973; & Galin, 1976) The critical thinking questions required problem-solving activities. Since this is a right-hemisphere specialization, it is reasonable that students who had been instructed using right-hemisphere techniques would perform better.

<u>Attitudes</u>. Hypotheses 4 and 5 concerned students' attitudes toward science immediately following the treatment. Hypothesis 4 concerned attitudes toward the unit of study while Hypothesis 5 concerned attitudes toward science in general. Data analysis revealed that both hypotheses were significant, but in opposite directions. Hypothesis 4 was significant favoring the 4MAT System approach, $p < .05$, and Hypothesis 5 was significant favoring the restricted-textbook approach, $p < .05$.

It was anticipated that students in the 4MAT System approach group would have more positive attitudes toward the unit of study than students in the other group. This was expected because all students were instructed and able to work part of the time in their preferred learning style and hemisphere preference. In addition, the variety of activities the 4MAT System utilizes would likely be more interesting to the students and therein produce more positive attitudes.

It was not predicted that students in the restricted textbook group would show more positive attitudes toward science in general than the 4MAT System approach group. The investigator can find no explanation to explain these results adequately. It is possible that students in the former group overreacted and staged a "protest vote." They did not enjoy the unit of study but do, on the whole, like science. They, therefore, might have reacted more strongly to the questions about science in general to show that they really do like science. The 4MAT System approach group, on the other hand, did not have this strong negative reaction to the unit of study, and, therefore, they felt no compulsion to show that they really do like science.

Implications

The use of the 4MAT System instructional approach may have merit for school utilization and for research. As educators strive to find ways to motivate students and to focus their attention, they need to use 4MAT, and they need to conduct research on its impact and effectiveness.

One must remember that, like all experiments, this research project had limitations delineated by its design. This study was with 6th grade students in three schools and one school system, and results can only be generalized to other similar situations. Additional research is necessary before generalizations and conclusions can be made to populations other than those studied.

The findings of this investigation are important because they increase the body of data and literature on the effectiveness of the 4MAT System approach to instruction. As of this date, only one research study (Wilkerson, 1986/1987) has been reported on the 4MAT System, and while that study showed significant results in favor of the 4MAT System, obviously additional research is needed.

A need for reform in education has been cited frequently in recent years. There is general consensus that students need to be taught to apply, analyze, synthesize, and evaluate information with increasing skill if they are to be prepared for the workplace of tomorrow's technological world. The results of this study indicate that the 4MAT System approach to instruction may hold promise to help meet this need. Curricula that are organized according to the 4MAT System, with teachers trained to properly teach the lessons, may well provide an answer to the question of what is the best route to take in educating our students.

Suggestions for Further Research

The 4MAT System is relatively new and little research has been conducted on it. Consequently, additional research would be beneficial in several areas. One would be to replicate the study with a heterogeneous group of students because at this time we have dta only on groups of academically gifted students.

Another research project could be to replicate the study or conduct a similar one at other grade levels. The effects of the 4MAT System approach as it interacts with maturational or cognitive levels thus could be investigated.

Research using a larger population that would increase the likelihood of having more subjects in each of the hemisphere-dominance categories might shed light on the interaction of the effect of hemisphere dominance on achievement.

Additional research on the attitudes of students taught using the 4MAT System also deserves attention. Using more sophisticated measures of attitude toward science and mode of instruction may yield more information on instructional affects of the 4MAT System approach.

The long-term effect of the 4MAT System is another area for research. Longitudinal studies of students taught using the 4MAT System over a period of a year or more would provide interesting data.

Finally, a study of achievement, gender, and instructional format may yield valuable information about the most expedient ways to teach.

Summary

This investigation sought to assess the affect of use of the 4MAT System approach and the restricted textbook approach on achievement and attitudes of sixth grade academically gifted students.

There were significant advantages in favor of the 4MAT System approach in overall achievement, achievement on critical thinking questions, and attitudes toward the unit of study. There were significant advantages in favor of the restricted-textbook approach in attitudes toward science in general. There were no significant differences on achievement of knowledge-level questions.

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APPENDIX A

OBJECTIVES FOR THE UNIT OF STUDY

OBJECTIVES

FOR THE UNIT OF STUDY

Upon completion of this unit, the student will be able to:

1. State Newton's First Law of Motion and apply it to situations involving the motion of objects.
2. Recognize and correctly choose the correct definitions for the following terms: motion, distance, speed, velocity, acceleration, mass, weight, friction, newton, force, buoyancy, gravity, and spring balance.
3. Apply the concepts in Objective 2 to situations involving Newton's First Law of Motion.
4. Calculate the speed and acceleration of objects.
5. State Newton's Universal Law of Gravitation and apply it to given situation.

APPENDIX B

4MAT SYSTEM LESSON PLANS

4MAT SYSTEM LESSON PLANS

QUADRANT ONE--INTEGRATING EXPERIENCE WITH THE SELF

--CONCERN WITH PERSONAL MEANING--GIVE THEM A REASON

--The Innovative Learner's most comfortable pla

--Answer the question "WHY?"

--Teacher's role: Motivator and Witness

--Method: Simulation to encourage brainstorming for
imagination, innovation, and empathy

Step 1--Right Mode: Create an Experience

Objective: To help the students understand that motion is an integral part of their everyday lives motion.

Activity: Students will listen as the teacher takes them through guided imagery of the motion they have experienced from the [illegible] they arose until they arrived at school.

Materials: None

Evaluation: The engagement of the students.

Script:

****

The teacher should create the following experience in a soothing, deliberate manner, allowing students sufficient time to visualize the trip on which they are being taken.

****

"Today I want to take you on a trip, a trip of a different kind than you usually take. This trip will be in your mind. Before I begin, I want you to get comfortable."

****

Wait until the students are settled down.

****

"I want you to close your eyes, breathe deeply, and completely relax. Try not to think about anything special at this point, just try to relax. Be sure to keep your eyes closed."

****

Give the students a few moments to relax and feel comfortable with this activity.

****

"Now, I want you to think about what you have done today that involves motion. It's this morning, and you have just awakened and are lying in bed. You haven't moved yet."

****

Pause

****

"Then you make your first move. What kind of motion was it? Did you hop out of bed? Did you slowly get up? How did this movement make you feel?"

****

Pause

****

"Now you're up; what did you do first? Take a few moments and think about your movements from the time you got up to just before you left your home to come to school. Think about everything about getting dressed. What did you put on first? Next? What did you do after getting dressed? Did you make your bed? Did you eat breakfast? Did you open and close any doors or drawers? Think of all your movements getting ready for school."

****

Allow the students a few moments to think about this.

****

"Now you're on your way to school. How did you get there? Did you walk? Ride a bus? Ride your bicycle? Ride in a car?

****

Pause

****

"What did it feel like when you were going to school? Feel yourself moving; was it hard work? Was it pleasant?

How long did it take? What kind of stops and starts were there? How did it feel to stop and start? Was it bumpy? Which directions did you move?"

****

Pause

****

"Now you've arrived at school. Think about opening the door. What was it like? Did you push or pull it open? Was the door heavy? Did you have trouble opening it?"

****

Pause

****

"When you were inside, where did you go first? Was it crowded? Did you bump into anyone? What happened when you touched someone or something--did you move?

****

Pause

****

"OK, you can open your eyes now. How did it feel to imagine your trip to school today? Could you feel the motions you had gone through? Was it hard to remember all the motions you went through?"

****

Allow time for the students to briefly discuss how they <u>felt</u> during this experience.

****

(Time: approximately 10 minutes.)

<u>Step 2--Left Mode</u>: Analyze the Experience

<u>Objective</u>: To have the students analyze the kinds of motion they have experienced that day from the time they awoke until they got in the school building and to share this motion with another.

<u>Activity</u>: Ask the students to get into groups of two and share with one another they kinds of motion and cessation of motion they experienced during the day.

<u>Materials</u>: None

<u>Evaluation</u>: Quality of the students' engagement in the discussion.

<u>Script</u>: "Now I want each of you to share the motions you have gone through today with the person sitting next to you. Each of you should take about five minutes as you tell each other what you did. Talk about the kind of motion involved; were you moving up and down or forward and backward? What did it feel like when you stopped moving? Could you feel any pressures when you stopped? Was it hard or easy to stop?"

****

Allow time for the students to share their feelings. Walk around the room and listen to the conversations students are having to be sure they are on task.

****

(Time: Approximately 10 minutes)

QUADRANT TWO--CONCEPT FORMATION

--CONCERN FOR THE FACTS AS EXPERTS SEE THEM--TEACH IT TO THEM

--The Analytic Learner's most comfortable place

--Answer the question "WHAT?"

--Teacher's Role: Information Giver

--Method: Informational

Step 3--Right Mode: Integrate Observations Into Concepts

Objective: To integrate Quadrant One's experiences with motion and Newton's First Law of Motion (the Law of Inertia).

Activity: Students will listen as the teacher leads them through a guided imagery of life if Newton's First Law of Motion, the Law of Inertia, existed without restraints on it. This will be followed by the section of the videotape, "Toys in Space," that poses questions about motion of a paper airplane in a gravity-less environment.

Materials: "Star Wars" audio tape; tapeplayer; videotape, "Toys in Space;" video cassette player; posterboard with Newton's First Law of Motion written on it

Evaluation: Engagement of the students in the imagery and videotape.

Script: "Well, we've all had a chance to visualize and then to talk about the kinds of motion we've experienced today. Now I'd like to take you on another trip. I want you to close your eyes again and just relax. I'm going to play some music to help you get in the mood for the trip we're going to take."

****

Play the theme song from Star Wars for 10-15 seconds while the students relax to get ready for the guided imagery. Continue to play the music softly as you begin speaking.)

****

"Once upon a time, a long time ago, in a galaxy far, far away, there was a school in Chapel Hill, North Carolina. Some things at this school were very different from what it is like today. Things didn't always move like they do today. Sometimes, people found it was difficult to get things moving, but once they started moving, they needed no energy, and they didn't stop. What would it be like to be able to move quickly and easily without using any energy? People had to be very careful, though, not to get carried away as they moved.

"I want you to pretend you are in school in that far away time, and try to imagine life where things moved like that. You and a friend decide to ride bikes during recess. You pedal like mad to get going really fast. All of a sudden, you are moving on your own. You don't have to pedal any more. You can go around any place you want-- uphill, downhill, around the buildings-- without needing to pedal. What a wonderful feeling! It's like flying; you feel free as a bird. All of a sudden, your bike goes over a bump, and your find you are airborne. You're flying! You can turn your bike any direction you want. Can't you just feel the breezes around you?! Ah, this is the life!"

****

Pause

****

"Oh, there's the whistle! Recess is over, and it's time for class again. You try to get your bike down, but you can't. What will you do? You can't stop moving! Oh, no! What will happen? You are riding near your friend, yelling at each other as you try to figure out a way to get down. If only that famous super power Inertia Woman were here to help you!

"Then, all of a sudden, from out of nowhere, Inertia Woman shows up. She carefully shows you how to have an outside force on your motion, and you glide down to earth. As she leaves you there, she gives you some advice. `You had better learn about the laws that govern me so this doesn't happen again. I may not be around to help you the next time!' With that, Inertia Woman moves on to do her job in another part of the galaxy."

****

Turn off music.

****

"Well, that's the end of my story. Now, open your eyes. You are safely back in your own galaxy in your own school. How did you like that story?"

****

Elicit a couple of responses.

****

"Who remembers the name of the super power who helped you get back to earth?"

****

Inertia Woman

****

"What was the advice she gave you?"

****

Learn about the Law of Inertia

****

"Does anyone have any idea what inertia is?"

****

Elicit responses. If no one knows, state that inertia is a property of motion having to do with forces that start and stop things.

****

"Now I'd like to show a videotape about flying a paper airplane in space and the way the airplane acts in space when the forces around it are different from those on earth. As you watch the tape, try to think about the differences between the paper airplane on earth and in space."

****

Show the videotape.

****

"What did you think of the paper airplane in space? How was the airplane like a similar one here on earth?"

****

It looked the same and could go forward in a similar manner. It couldn't go backwards in either situation.

****

"How was it different?"

****

When it hit the wall, it bounced back in space. It could fly with a very small push, and would continue to move until it hit something else. Small air currents were enough to make it move in different directions.

****

"Think back to the videotape. Remember how the paper airplane floated in space and would keep going until it hit something? It didn't fall down like it would on earth, did it? That's because the force of gravity and other forces aren't the same in space as they are on earth. The paper airplane in space is a good representation of Newton's Law of Inertia. What's amazing is that he wrote his laws 300 years ago without ever having been in space!"

(Time: Approximately 20 minutes.)

(Note: This is the end of Day 1)

Step 4--Left Mode: Develop Theories and Concepts

Objective: To develop the overall concepts and vocabulary connected with the Law of Inertia.

Activity: A five-minute videotape segment from the Public Broadcasting Service "Eureka!" science series on Newton's First Law will be shown and discussed. Vocabulary words and definitions will be distributed to the students and written on an overhead transparency and then will be discussed. Written material on the law and connected vocabulary will be read.

Materials: Sheet with definitions; information sheets on Newton's First Law of Motion; videotape, "Eureka!;" videotape player; poster on the First Law of Motion

Evaluation: Engagement of the students in completing the activities.

Script: "Yesterday we were talking about motion and inertia. We said the Law of Inertia is another name for Newton's First Law of Motion. Who can state this law?"

****

Elicit definition. If they know the definition, respond positively, as follows. Otherwise, have a student read the definition from the poster.

****

"That's great! You were really listening well yesterday. I have a videotape about inertia I'd like to show you. Before we see it, though, I'd like to read a little about inertia. I'm going to pass out these sheets. When you get one, begin reading the first page and the first couple of lines on page 2--up to where the section on forces begins."

****

Pass out information sheets. Allow a couple of minutes for students to read the sheets.

****

"Now that you've read about inertia, I want you to watch a videotape about inertia. I want you to pay special attention to what inertia is, how objects begin moving, and how objects stop."

****

Show videotape on inertia.

****

"That was a fun way to tell you about Newton's First Law. Let's think about what we just saw about inertia. Objects are basically lazy, aren't they? What do nonmoving objects naturally want to do?"

****

Continue to be at rest

****

"Great! OK, now who can tell me what moving objects naturally want to do?"

****

Continue to move

****

"Very good! I think you are all really catching on to this. If an object is moving, it wants to continue moving. Does anyone remember in what direction it wants to continue to move?"

****

It will go in a straight line. Refer at will to the posterboard with Newton's First Law written on it.

****

"Good. Who can tell me about how fast the object will go once it is moving?"

****

It will continue at a constant speed.

****

"That's right. Now, I want each of you to think about how things move here on earth. Do they keep moving without stopping?"

****

No

****

"Right! Look at the Law of Inertia we have written on the posterboard. Does anyone see anything in the Law of Inertia that might explain why things don't keep on moving?"

****

...unless acted upon by an unequal force.

****

"That's right; things keep moving unless acted upon by an unequal force.

"Before we go any further, let's talk about those forces that make things stop. There are some words and definitions that will help you understand these forces on this vocabulary sheet. You'll need to know these, so pay close attention as I go over it."

****

Pass out the vocabulary sheets. Using the overhead transparency with the definitions written on it, discuss each word and its definition.

****

"Now I want you to finish reading your information sheets on forces affecting inertia. Pay special attention to the forces that affect forward and backward motion and the one that affects up and down motion. When you are finished, we'll discuss it."

****

Allow time for the students to read.

****

"OK, let's discuss what you've just read. Let's look at the first three topics discussed in the sheet. Inertia is the tendency for things to keep on doing what they are already doing. Force is a push or a pull that can change inertia. Vertical forces pull things down and push things up. Gravity is the force that interrupts the inertia of things and pulls them down toward the earth; buoyancy is a force that pushes things up.

"The next topic mentioned is mass versus weight. What is the difference between these two words?"

****

Mass is the quantity of matter; it is invariable. Weight is the amount of force gravity exerts on an object; it varies with the object's location in the Universe.

****

"Now, how about horizontal or back and forth forces? What is the force that slows things down in a straight line or horizontal direction?"

****

Friction

****

"Good. Friction slows down straight line motion. There are three kinds of friction: sliding, rolling, and fluid. Which kind of friction does it take the most force to overcome?"

****

Sliding friction

****

"That's right. That's why it takes more effort to push something on the ground than to put it in a wagon and pull it along. Adding a lubricant to a machine or a wheel changes sliding friction to fluid friction where the least force is required to move some something. When you are riding your bike, it is a combination of two kinds of friction that slows you down: rolling friction and fluid friction. Does anyone remember another name for the fluid friction that slows your bike down?"

****

Air resistance

****

"Good. Now, we've talked about speed before. Velocity is like speed, excepting you add a direction. When might it be important to know your velocity, not just your speed?"

****

Accept any reasonable answer that has to do with a direction being important when considering motion such as airplanes landing or finding an unknown location.

****

"What is acceleration?"

****

The rate of change in velocity of an object

****

"That's right. If an object is not moving at a constant speed, or if it is changing direction, it is accelerating. If you are accelerating you are going faster or slower, or you are changing direction, because velocity involves speed and direction. Sometimes when an object slows down it is called deceleration, but it is still acceleration. Therefore, if an object is changing direction and/or speed, it is accelerating.

"Now, answer this. If you are riding your bike down the street in a straight line at a constant speed, you are not accelerating; why aren't you?"

****

You are maintaining the same speed and direction.

****

"Good. Now, if you are riding around a track at a constant speed, you are accelerating. Why?"

****

You are changing direction when you ride around the track.

****

"OK, let's wrap this up now. What unit do scientists use to measure force?"

****

The newton

****

"That's right; the newton is used to measure how much a force changes the speed of an object of a given mass. What is the definition of 1 newton?

****

The amount of force required to accelerate 100 grams at 10m/sec/sec (10m/sec^2)

****

"Good, and the force of one newton is equal to about how many grams?"

****

1 N = ~100 gms.; specifically 100 gms = .98 N

****

"Fine. A spring balance is used to measure the force, the number of newtons, required to do any work. Don't forget, newtons are also used to measure weight because weight is a measure of force.

OK. Are there any questions about any of these terms?"

****

Answer any questions they may have.

****

(Time: approximately 35 minutes)

QUADRANT THREE--PRACTICE AND PERSONALIZATION

--CONCERN FOR HANDS-ON EXPERIENCE--LET THEM TRY IT

--The Common Sense Learner's most comfortable place

--Answer the question "HOW DOES THIS WORK?"

--Teacher's Role: Coach/Facilitator

--Method: Facilitation

Step 5--Left Mode: Practicing Defined Givens

Objective: To reinforce concepts through use of hands-on investigations concerning Newton's First Law of Motion.

Activity: Students will reinforce the information learned by completing a crossword puzzle and two hands-on activities.

Materials: Information sheets, crossword puzzle, 4 wind-up cars, 12 feet of 1/2" plastic tubing, 4 ball bearings, 12 index cards, 4 metersticks

Evaluation: Completion of the assigned activities.

Script: "We have been talking about Newton's First Law of Motion. As a review of what we've been talking about today, I'd like for you to complete this crossword puzzle on Newton's Law of Inertia. It covers the major vocabulary words we have just discussed. There are about 10 minutes left in this period. Complete the puzzle, and then we'll continue with some other activities about motion tomorrow."

(Note: This is the end of Day 2.)

"Yesterday we were talking about Newton's First Law of Motion, the Law of Inertia. Today I want you to do some activities involving the law.

"There are two activities. One involves measuring speed and the other involves investigating the direction a ball will go when it exits from a piece of plastic tubing."

****

Pass out the worksheets.

****

"First, let me go over the directions with you. It will be important to follow directions, so listen carefully while we go over the directions. (Student), please read the directions at the top of the first sheet."

****

Student reads

****

"Good, thank you. Are there any questions?"

****

Answer any questions they may have.

****

"Now, (Student), please read the directions on the second sheet."

****

Student reads

****

"Good, thank you. Are there any questions?"

****

Answer any questions they may have.

****

"OK, divide into groups of three and begin your work. You'll have 25 minutes to do this, so watch your time."

****

Wander around as the students work on their assignment. Be sure they are following the directions carefully and that they are staying on task.

****

(Time: approximately 25 minutes)

Step 6--Right Mode: Adding Something of Themselves

Objective: To relate the content they have learned to their personal lives.

Activity: The students will choose one of several activities and will plan how they want to present the information to others via their activity.

Materials: List of activities

Evaluation: Involvement of the students and production of a plan for their activity

Script: "Now that you've had a chance to practice some activities relating to the First Law of Motion, I want you to tell someone else about Newton's First Law of Motion. This will be a creative activity, so you can put a little bit of yourself into it. You may choose from the list I have for you, or you may think of an activity for yourself. If you choose an activity of your own, please tell me what you are planning."

****

Pass out list.

****

"Take a look at the list. Do you have any questions?"

****

Answer any questions they may have.

****

"You will have 20 minutes to plan this activity, so let's get started."

****

Encourage students to begin right away. Walk around and monitor the students as they work, giving assistance as needed. If students are ready for the next step before the end of the time period, introduce them to the next step individually.

****

(Time: approximately 25 minutes.)

(Note: This is the end of Day 3.)

QUADRANT FOUR--INTEGRATING APPLICATION AND EXPERIENCE

--CONCERN FOR ACTION, DOING--LET THEM TEACH IT TO THEMSELVES AND SHARE WHAT THEY LEARN WITH OTHERS

--Answer the question "IF?

--Teacher's Role: Evaluator/Remediator

--Method: Self-Discovery

Step 7--Left Mode: Analyzing their Personalization for Originality and Relevance

Objective: To reinforce student ability to understand Newton's First Law of Motion

Activity: Students will analyze and carry out their plan demonstrating some aspect of Newton's First Law of Motion.

Materials: Old magazines, colored marking pens, posterboard, glue

Evaluation: Analysis and completion of the plan in Step 6.

Script: "Yesterday you created a plan to teach someone else about Newton's Law of Inertia. Now I want you to think about that plan. Does your plan do what you want it to do? Does it tell someone about the law? What kinds of questions might someone have about it? See if the project you have created actually tells about the law. After you have analyzed your plan and are ready to begin your project, let me see what you are planning before you begin.

"When you are through analyzing, I want you to actually make the project you have created. There are some old magazines, colored markers, sheets of posterboard, and glue up here to use in making your project when you are ready. You will have about 20 minutes to complete this project, so work quickly. I'll be here to answer any questions you may have."

****

Wander around and answer questions and make sure the students are on task.

****

(Time: approximately 25 minutes)

Step 8--Right Mode: Doing It and Applying What They Have Learned to New, More Complex Experiences

Objective: To share the completed activities.

Activity: Students will meet in groups and share and explain the activities they have devised.

Materials: Projects the students have completed

Evaluation: Quality of the students' engagement in the presentations.

Script: "All right now. You should be finished with your activity. I want you to get into groups of four."

****

Use groups of three if time is running short.

****

"I want each of you to take about three or four minutes to present your project to the other members of your group. Are there any questions? OK, begin."

****

Wander around the room listening to the presentations. Help out as necessary to keep the students on task. After 15 minutes or so, bring the group back together.

****

"Those were certainly some good ideas. I think you really understand about the Law of Inertia. Tomorrow we will have a short quiz over the material we have been studying. The questions will be multiple choice, true-false, and which one doesn't belong. You will need to study the vocabulary words we learned. Are there any questions?"

****

Answer any questions they may have.

****

"OK, see you tomorrow."

(Time: approximately 20 minutes.)

Newton's First Law of Motion

An object at rest tends to stay at rest, and an object in motion tends to stay in motion in the same direction and at a constant speed unless acted on by an unequal force.

(Example of format for poster)

Newton's First Law of Motion

In 1687, a man named Isaac Newton published three observations about motion. Today we know these observations as Newton's Three Laws of Motion. This paper is about the first of these laws.

Newton's First Law of Motion states: "An object at rest tends to stay at rest, and an object in motion tends to stay in motion in a straight line and at a constant velocity unless acted upon by an unequal force." This tendency to keep on doing what you are already doing is called inertia. For this reason, Newton's First Law of Motion is also called the Law of Inertia.

Your own experiences tell you the first part of this law is true. After all, the only place we have ever seen a ball start rolling on its own or a bike ride down the street on its own is in the movies or on T.V. An object that is not moving will stay that way until something makes it move.

On the other hand, your own experiences may seem to tell you that moving objects don't just keep moving--they eventually stop. If you throw a ball, it stops on its own or is caught; if you don't ep pedaling, your bike will stop. Believe it or not, IF there were no unequal forces around, that ball and that bike WOULD keep moving in a straight line at a constant velocity FOREVER! Hard to believe? Perhaps, but it is true. Let's discuss some of those forces and some concepts that may help you to understand about the First Law of Motion.

FORCES

A force is a push or a pull that is exerted on an object. At any given time, all objects are either moving, not moving, or changing directions. It is force that gives energy to an object to make it start moving, stop moving, or change its movement. While people and objects produce some forces, other are naturally occuring. There are two major forces you need to be concerned with at this point, gravity and friction.

GRAVITY. Newton's Law of Universal Gravitation states that all objects naturally have a pull or an attraction toward each other; this attraction is called gravity. The strength of the attraction of two objects is determined by the mass of the objects and their distance from each other. For example, there is a gravitational pull between you and the paper you are holding, but the masses involved are so slight you don't notice it. On the other hand, the earth is very massive, so it has a huge pull on objects. The force of gravity pulling things toward earth is so much larger than the forces pushing things up that gravity will usually cause objects to fall to earth. The downward-pulling force of gravity is opposed by buoyancy, a lesser force that pushes upward.

Mass is the quantity of matter in an object while weight is the amount of force gravity exerts on an object in any given part of the universe. This gravitational force varies with the mass and distances of the objects being attracted. For example, there is less gravitational pull on top of a mountain than near the ocean here on earth. There is almost no gravitational pull in space because the distance from the earth or other planets and moons is so great. This is the reason people are essentially weightless in space and float around. The mass of the our moon is about one-sixth that of the earth's, so its gravitational pull is one-sixth that of earth, and objects on the moon weigh one-sixth what they would on earth.

FRICTION. The force that causes objects to stop is called friction. There are three kinds of friction: sliding, rolling, and fluid. Sliding friction is the force that stops you when you slide across a gym floor in your stocking feet. Rolling friction is the force that stops you when you are coasting on your bike. Fluid friction is the air resistance or water resistance that slows things down when they are falling through the air or liquid. Sliding fricition is the strongest friction force, followed by rolling and fluid friction. This is why it's easier to pull a box on wheels than flat on the ground. Lubricants are used in machines to change sliding friciton to fluid friction so there won't be so much friction between two sources. Thus fluids can act as a force to push things up (buoyancy), and they also can act as a force to slow things down (friction).

MEASURING MOTION

Motion is a change in position of an object. It is measured by how far and how fast the object is going. Distance is a measure of how far an object has moved. Speed is the distance an object has moved in a given period of time. If an object is going at a constant speed, it is covering the same distance every second it travels. The formula for speed is $S = D/T$, speed equals distance divided by time.

Velocity is a measure of the speed and direction of motion. The velocity of an object is determined not only by its speed, but also by the direction in which it is going. For example, if you are told a car is going 50 km/hr, you know the car's speed. If you are told a car is going 50 km/hr east, you know the car's velocity--its speed and direction.

Velocity is used in determining the acceleration of an object. Earlier we said that if an object is covering the same distance every second, it is traveling at a constant speed. If the distance is not the same every second, the object is accelerating, or changing its rate of speed. Acceleration is the rate of change in velocity of an object. Another way of saying this is that acceleration is a measure of the direction and rate of speeding up or slowing down of an object in a given period of time. Because acceleration involves a change in velocity, it can only occur when an unequal force acts on an object. The formula for acceleration is A = CV/T, acceleration equals change in velocity divided by time.

Since velocity is measured in units of distance divided by time (for example m/sec or km/hr), and acceleration is a measure of velocity change in a given period of time, acceleration is measured in m/sec/sec. This tells you how much the speed (m/sec) changes every second. This is also written m/sec^2. If an object is accelerating at the rate of 2 m/sec/sec (2 m/sec^2), its speed is increasing at the rate of 2m/sec every second.

MEASURING FORCE

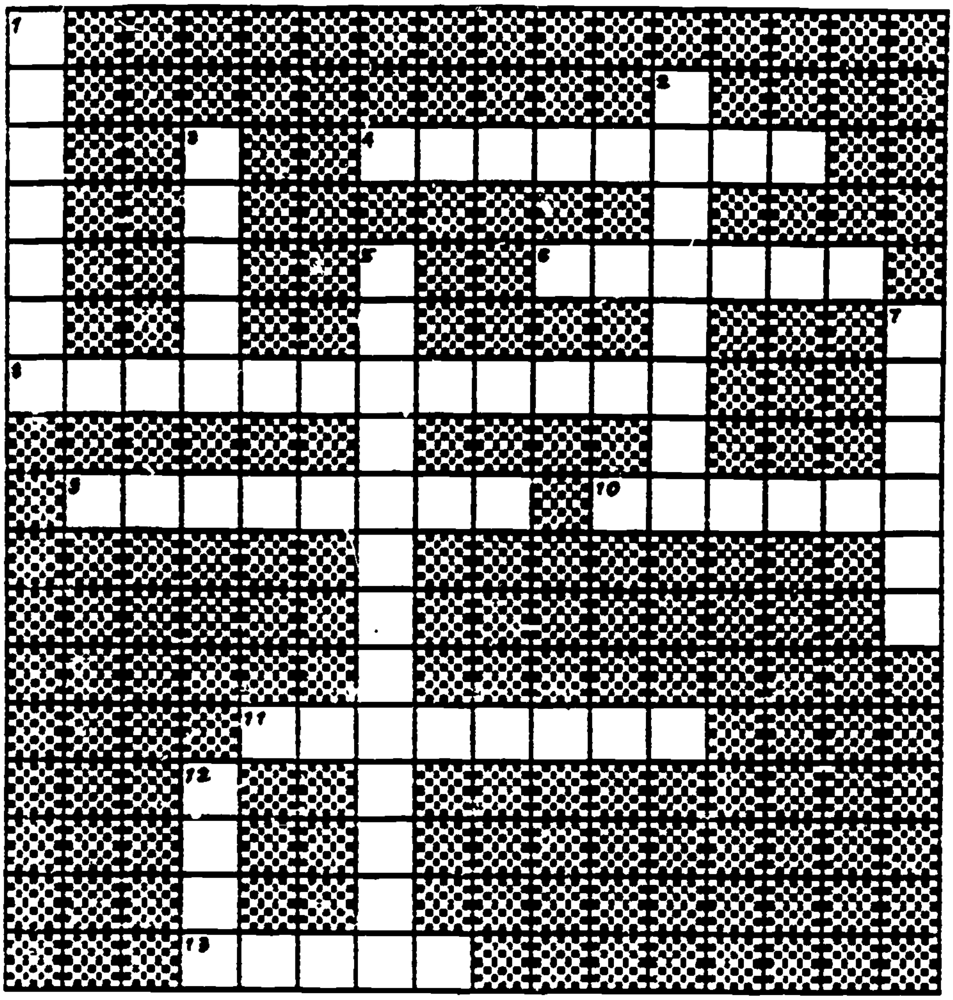
The metric unit used to measure force is the newton. Forces affect the motion of objects, and the newton is used to measure how much a force changes the speed of an object of a given mass. (Note that scientists use the term mass not weight. Remember that the weight of an object is the amount of force that the earth's gravity exerts on an object, so weight will vary according to the gravitational pull on it, but that the mass, the quantity of matter, will always remain the same.)

One newton (N) is equal to the amount of force required to accelerate 100 grams at 10m/sec^2. On earth, the force of one newton equals about 100 grams (.98 N = 100 gms). A special scale called a <u>spring balance</u> is often used to measure force in newtons. Since weight is a measure of force, it is measured in newtons just like other forces.

MOTION VOCABULARY WORDS

1. force = a push or pull exerted on an object
2. newton = metric unit of force
   --measures how much a push or pull changes the speed of an object of a given mass
   --1 N = the force that changes the speed of a 1 kg mass by 1 m/sec)
   --100 gm = .98 N
3. mass = the quantity of matter an object
   --mass doesn't change
4. weight = the amount of force gravity exerts on an object
   --weight varies with the amount of gravitational pull
5. spring balance = an instrument that measures force
6. friction = force that opposes the horizontal movement of an object
   --three types of friction: sliding, rolling, and fluid
7. motion = change in positon
8. distance = how far an object has moved
9. speed = distance traveled in a particular period of time
   --s = d/t
10. velocity = speed and direction of an object
11. acceleration = rate of change in velocity
    --a = cv/t
    --measured as distance/time/time (ex. m/sec/sec)
12. negative acceleration = deceleration = slowing down
13. inertia = the tendency of things to keep on doing what they're doing
14. buoyancy = a force that pushes upward on objects
15. gravity = a force that pulls downward on objects
    --varies with the size of the objects and the distance between the objects
16. lubricant = a substance such as grease that is designed to change sliding friction to fluid friction

MOTION



ACROSS CLUES

4. force that opposes the horizontal movement of an object
6. change in position
8. rate of change in velocity
9. force that pushes up on an object
10. amount of force the earth's gravity exerts on an object
11. speed and direction of an object
13. distance traveled in a particular period of time

DOWN CLUES

1. tendency of things to keep on doing what they are doing
2. how far an object has moved
3. push or pull on an object
5. instrument that measures force
7. metric unit of force
12. quantity of matter in an object

Activity II: Determining the Speed of a Toy Car

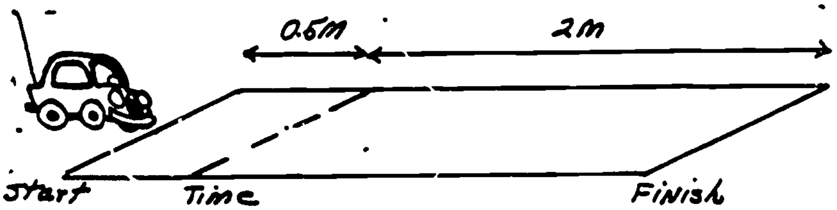
A. Materials and Equipment Needed:

Each group will need:

meter stick
battery-operated electric model car or truck
timer or clock with second hand
15 cm masking tape

B. Procedure:

1. Measure a 2.5 m track for your car on a smooth surface, such as a table top or floor. Use masking tape to mark "start", "time", and "finish" lines like those shown below.



2. Switch on your car and place it on the "start" mark. When it reaches the "time" mark, begin timing how long it takes to reach the "finish" mark. Record your time observation in the Data Table as "Trial 1". Time three runs using this procedure and record your observations.

Data Table

	Trial 1	Trial 2	Trial 3
Seconds for car to go 2 meters			

3. Compute the average for Trials 1-3.
Average time interval to travel 2 m = ______ seconds.

4. The relationship between speed and distance is stated:

$$\textbf{Speed} = \frac{\textbf{distance moved}}{\textbf{time interval}}$$

While it is being timed for this activity, the car moves a distance of 2 meters between the "time" and "finish" lines. Dividing this distance (2 meters) by the average time interval that you computed (for step 3) gives the average speed of the car for the three runs.

Substitute your value for the average time interval in the equation below, and calculate the average speed of the car.

$$\textbf{Average Speed} = \frac{\textbf{distance moved}}{\textbf{average time interval}} = \frac{2\text{ m}}{\_\_\_\text{ seconds}} = \_\_\_\_\textbf{m/sec}$$

5. Why is it best to repeat your measurements several times in an experiment like this one?

6. What is the purpose for letting the car run 0.5 meters before starting to measure the time?

7. If the car that you are using has different speed settings, change the speed setting and repeat the measurements. How does the calculated value for the car's speed change?

Activity// : Bent Barrel Ballistics

Scenario: In an old movie, *The Road to Bali*, Bing Crosby stands in the doorway of a hut and shoots a gun with a barrel that has been bent into a semicircle by a gorilla. The bullet, rather than offering freedom, traps Crosby and Hope in their hut by continuously circling the hut. After all, since the bullet had a circular path while in the barrel why shouldn't it continue its circular motion after leaving the barrel?

The Problem: Will an object already traveling in a curving path continue its curving motion when it is released?

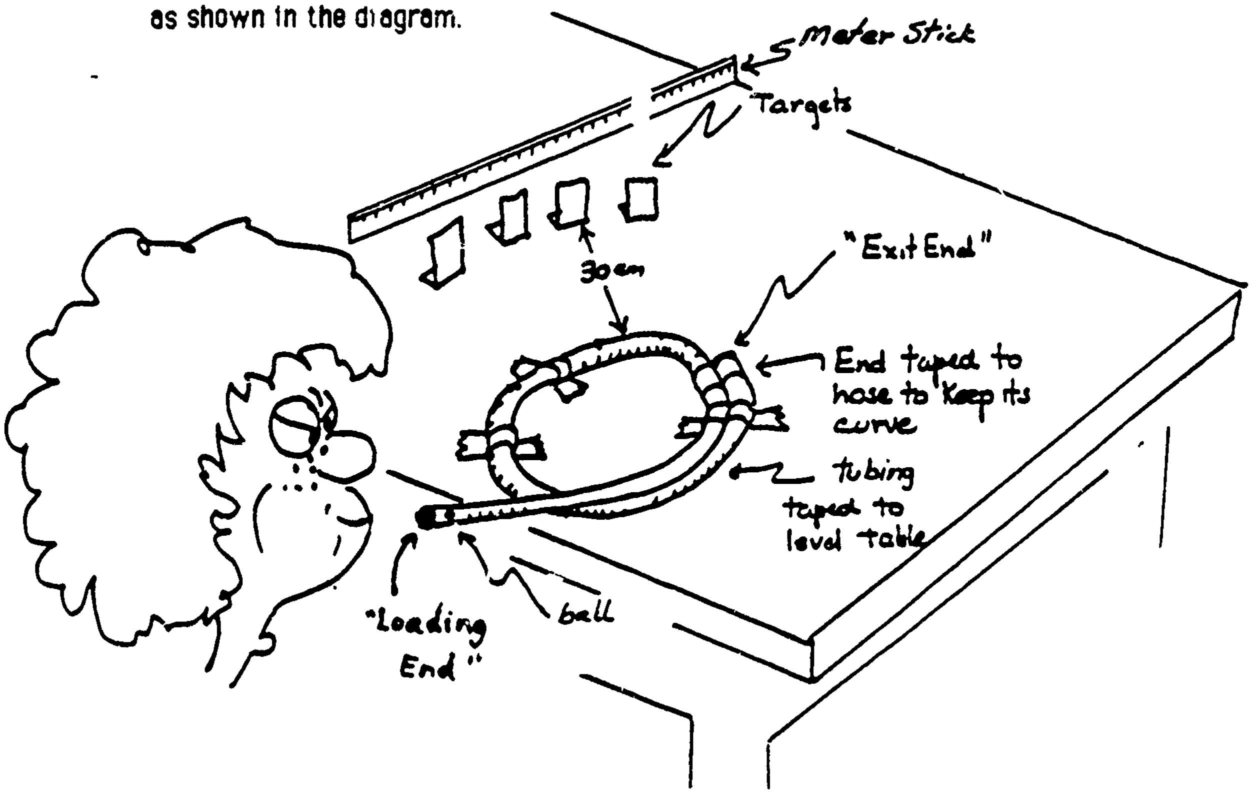
A. Materials and Equipment Needed:

Each group will need:

- 115 cm length of clear plastic tubing (tubing 1"x 3/4" used in M1)
- marble or ball bearing that can roll freely inside the tubing (the "bullet")
- masking tape
- index card "target" (about 3 cm wide) for each person
- meter stick or ruler

B. Procedure:

1. Coil the garden hose into a 20 cm diameter circle, and tape it down as shown in the diagram.



Check the accuracy of your set-up by answering the following questions:

Is the section of garden hose coiled and taped into a 20 cm diameter circle as seen on the next page? _____

Is the "exit end" or the muzzle taped to the coil so the "end" curves with the coil? _____

Is the tape far enough away from the "loading end" of the coil so that it can be lifted about 10 centimeters above the table? _____

Is the "exit end" pointed so the ball will shoot along the level table? _____

Is the coil taped to the table so it will not move with repeated shootings? _____

Is the "bullet" just a little smaller than the tube, but small enough to easily roll in the tubing? _____

When you can answer "yes" to all of these questions, do the steps below.

2. PREDICTIONS: Write your name on your index card "target". Predict the path of the "bullet" and place your "target" on the table where you think it will be hit by the ball shooting out of the tube. The target must be at least 30 cm from the "exit end" of the tube.

3. Raise the "loading end" of the tube slightly and drop in the "bullet". The ball zooms around in a circular path inside the tubing before it shoots out. Whose target was hit? __________

4. Put a meter stick in front of the "exit end" so that it will stop the shots from the coil. The meter stick should be about 30 cm from the end of the tube. Shoot the bullet at least 5 more times and keep track of where the bullet hits the meter stick.

5. From observing the "hit marks" on the meter stick in relation to the "exit end" of the tube, describe the motion of a bullet after it leaves the curved barrel.

____

____

____

6. State your own hypothesis: Will objects continue in curved motion when they are free to move without constraint?

____

____

____

____

NEWTON'S FIRST LAW OF MOTION ACTIVITIES

You are to plan an activity to demonstrate/teach Newton's First Law of Motion (Law of Inertia) to someone else. Choose an activity from the following list. If you wish to develop your own activity, please check with your teacher before you begin planning it.

1. Make a poster.
2. Make up an original investigation or experiment.
3. Make up a demonstration.
4. Design an instrument to measure inertia.
5. Write a poem that explains inertia.
6. Design an investigation that will demonstrate inertia in space.
7. Make up a game that will teach about inertia.
8. Make a collage to describe inertia.
9. Write a story that explains inertia to a 5-year old.
10. Write a letter home from a journey on a space ship explaining about how and why things move in space.
11. Make up a TV commercial "selling" inertia.
12. Design a worksheet to practice concepts about inertia.

HAVE FUN!!

APPENDIX C

RESTRICTED-TEXTBOOOK LESSON PLANS

TEXTBOOK APPROACH LESSON PLANS

Text: "Mechanics," Unit 6, Chapters 22 and 23, pp. 504-512, 534-543, 546-549. General Science, A Voyage of Discovery, Englewood Cliffs, NJ: Prentice-Hall, Inc., 1986.

Lesson One: Force and Friction

Objectives: The student will be able to:

1) Describe force and explain how it is measured
2) Name and compare three types of friction
3) Determine the number of newtons in a given weight

Activities: Introduce Newton's First Law of Motion using a diaglogue of a hypothetical crew on a space ship. Read and discuss written material about force, how force is measured, and mass versus weight. Discuss some examples of measuring force. Determine the number of newtons in a 1 kilogram mass on Earth. Discuss equal and unequal forces and work a problem involving combined forces. Define and discuss types of friction.

Materials:

1) Photocopied excerpts from text
2) Vocabulary lists
3) Blank overhead transparency and pens
4) Overhead projector

Time: 45 minutes

Script: "Today we are going to begin a new unit on mechanics, which is the science of motion and the energy associated with motion."

****

Hand out the photocopies of the text material. Assign four students to read the parts of the navigator, captain, first officer, and narrator on p. 505. For ease in reading, the name of the part and the material to be read are highlighted on four of the copies. When the reading is finished, thank the students and continue with the rest of the lesson.

****

"That was a space-age look at motion. Our scientific ability hasn't reached the point where we can send people safely beyond the solar system yet, but scientists do know a lot about motion and what forces they will have to overcome to send people to those far away places.

"Right now I'd like you to take a few minutes to read pages 507 and 508 as an introduction to motion. As you read, pay particular attention to what force is and how it affects motion."

****

Allow 3-5 minutes for the students to read the pages. At the end of five minutes, get the group's attention and begin the discussion.

****

"The first page of this chapter talked about bicycles. Why were the scientists working on bicycles? "

****

They wanted to improve the design of bicycles and see how fast they can go.

****

"So, knowing about force and work can help us know how to make things go faster.

"The chapter talked about force on page 508. Who can tell me what force is?"

****

A push or pull that is exerted on an object. Write the definition of force on the overhead transparency.

****

"That's right. What does a force do?"

****

It gives energy to an object to make it start or stop moving or change its movement.

****

"OK, what was the example the book gave about force?"

****

The door could be made to move faster or be kept from opening by using force.

****

"We've been talking about force and how it starts, stops, or changes the movement of objects. Now I'd like to take a look at how force is measured and some ways force can be made more effective. Does anyone know why Sir Isaac Newton was a famous scientist?"

****

He was a scientist who studied motion and gave us some very important laws about how things move.

****

"Newton made the people of the world change in how they looked at motion and weight. One of the things he did was to explain why things have weight, and he gave a special term to how we measure weight. I want you to read pages 509 to 512 in your handout materials. As you read, I want you to pay special attention to how weight is measured, to how forces are combined, and to what friction is and how it affects motion."

****

Give the students 10 minutes to read the pages.

****

"Scientists measure force in the metric unit of the newton, named after Sir Isaac Newton. A force affects the motion of an object, and a newton is a measure of how that force, how that push or pull, changes the speed of an object with a given mass."

****

Write "newton (N) = metric unit of force: measures how much a push or pull changes the speed of an object of a given mass" on the overhead transparency.

****

"This definition mentions mass. We've talked about mass before. Who remembers what mass is?"

****

A measure of the quantity of matter an object possesses

****

"What is the difference between mass and weight?"

****

Mass is the quantity of matter whereas weight is the amount of force that the earth's gravity exerts on an object. Remind them that mass stays the same while weight varies with the pull of gravity.

****

"What is the formula used to determine force?"

****

Force = mass x change in speed

****

"Can anyone think of a situation where a person's mass and weight are not the same?"

****

Elicit situations such as weightlessness in space, or people's moon weight being 1/6 of their Earth weight because the moon's mass is 1/6 that of the Earth. Tell the students their weight up on Mt. Mitchell in western North Carolina would be slightly less than here in Chapel Hill.

****

"The abbreviation for newton is a capital N. We said newtons measure how much the speed of an object with a given mass changes. Who can tell me what a force of 1 newton is equal to?"

****

Elicit answer and write on overhead transparency "1 N = a force that changes the speed of a 1-kilogram mass by 1 meter per second."

****

"Let's try some examples. Let's start with the one in the handout. If you have a 2-kg. weight and want to push it so its speed changes from 0 m/sec to 5 m/sec, what is the number of newtons needed to do this? Remember that force is equal to the mass of the object times its change in speed. We have a 2 kg. mass here. What is its change in speed, 0 to what?"

****

5 m/sec.

****

"Good. So what is the number of newtons needed?"

****

10 N.

****

"That's right. How did you determine that?"

****

Multiply the mass, 2 kg., by the change in speed, 5 m/sec., to get 10 N.

****

"Let's try another. If you want to move a 5-kg. object from 2 to 10 m/sec, how many newtons of force would you need?"

****

40 N.

****

"That's right. How did you get that answer?"

****

Multiply 5 times 8.

****

"I think you seem to be understanding. Are there any questions about what a newton is and how to determine the number of newtons needed to apply force?"

****

Answer any questions the students may have.

****

"Let's continue now. Scientists use an instrument called a spring balance to measure force. The object is attached to the spring balance and is pulled toward the earth by the force of gravity. The spring stretches, with the amount of stretch indicating the size of the force. The spring is marked off in newtons so the size of the force can be read directly from the scale."

****

Point out the picture of a balance on p. 509.

****

"Earlier we said weight was a force. Because of this, scientists measure weight in newtons, too, just like other forces. Look at the bottom of page 509 where it talks about weight. A mass of 1 kilogram is pulled toward the earth by gravity with a force of how many newtons?"

****

9.8 N.

****

"That's right, its weight is 9.8 newtons. In other words, weight in newtons is about ten times an object's mass in kilograms. If your mass is 50 kg., what is your approximate weight in newtons?"

****

About 500 newtons

****

"Good. The approximate weight would be 500 N, and your exact weight would be 50 kg. x 9.8 newtons or 490 N.

"Now, let's think about forces. If you and a friend push an object together, is it easier or harder than doing it alone?"

****

Easier

****

"That's right; it's easier because the two forces going in the same direction are combined. Now, how about if you and your friend are pushing in opposite directions? If you are pushing with exactly the same amount of force, what happens?"

****

Nothing, it would not move.

****

"...and if you are pushing against each other with unequal forces?"

****

The object would move away from the stronger force.

****

"Good. Look at p. 511. (Student), read what it says under `Activity' at the bottom of the page."

****

Student reads.

****

"The two forces are going in the same direction. What is the combined force?"

****

15,000 N.

****

"That's right, the forces are in the same direction, so you add them together to get 15,000 N.

"Now, let's think about opposing forces. When you are riding your bicycle, if you are just coasting along, you eventually stop because of friction. Friction is a force that opposes the horizontal motion of an object."

****

Write the definition of friction on the overhead transparency.

****

"It acts in a manner similar to when you and your friend are pushing in opposite directions on an object.

In this case, the forward motion of the bicycle is one force and friction is the other force. If the bike rider doesn't pedal to keep the forward motion going, friction is the stronger force and stops the bike. The handout mentioned three types of friction. Who remembers what they are and can give an example of each?"

****

Sliding, rolling, and fluid friction. Accept any reasonable answer for the examples.

****

"Let's review what we've talked about today. Here is a vocabulary list to help you learn thse words.

****

Hand out the vocabulary lists.

****

"Ok, what is a force?"

****

A push or pull exerted on an object

****

"Good. What is the metric unit for measuring force, and how do we measure force?"

****

Newtons, spring balance

****

"What is the difference between mass and weight?"

****

Mass is the total quantity of matter; weight is the amount of force the earth's gravity exerts on an object.

****

is friction?"

****

Force that opposes the motion of an object

****

"What are the three types of friction?"

****

Sliding, rolling, fluid

****

"Very good. Tomorrow we'll learn about distance and ways to measure motion."

Lesson Two: Distance and Velocity

Objectives: The student will be able to

1) Define distance
2) Determine the speed of objects
3) Define velocity
4) Describe motion in terms of distance, speed, and velocity
5) Define acceleration
6) Determine acceleration when given change in velocity and time
7) Discuss why circular motion always involves acceleration

Activities: Review previous day's definitions and concepts. Read about, define, discuss, and give examples of motion, speed, velocity, and acceleration. Complete an activity sheet to determine students' weight on Earth, Mars, Jupiter, and the moon.

Materials:

1) Photocopied excerpts from text
2) Overhead transparency with vocabulary words
3) Blank overhead transparency and pens
4) Activity sheet, "How Much Do You Weigh?"
5) Vocabulary lists

Time: 45 minutes

Script:

"Before we begin today, I'd like to review what we did yesterday."

****

Take about five minutes and review the definitions for force, mass, weight, newton, spring balance, and friction using transparency.

****

"Are there any questions about these definitions?"

****

Answer any questions the students may have.

****

"Now we're going to talk some more about motion. Motion is a change in position."

****

Write definition of motion on the blank overhead transparency.

****

"(Student), read the first two paragraphs on page 536."

****

Student reads about motion.

****

"So, when we talk about motion, we talk about movement only; we don't know how far or how fast something is going. To know that, we have to talk about distance and speed. (Student), read the next two paragraphs."

****

Student reads about distance and speed. Put the formula "speed = distance/time" on the overhead transparency.

****

"Talking about motion, speed, and distance tells us nothing about the direction something is moving. When you begin to talk about direction, you are talking about velocity. (Student), read the next two paragraphs."

****

Student reads about velocity. Write "velocity = speed and direction of an object" on the transparency.)

****

"Look at the picture at the top of p. 537. There are different speeds and velocities represented there. Look at the picture and tell me some things about the speeds and velocities you see there."

****

Spend only about two to three minutes on this activity. Talk about what things are moving as well as the directions they are moving.

****

"Let's talk a little more about velocities now. Who can tell me what we talked about yesterday about combining forces?"

****

Review about how direction and strength of forces determine the size and direction of combined forces.

****

"Very good. In a similar way, velocities can be combined. Look at the top of p.538. (Student), read the two paragraphs there."

****

Have student read. Then discuss same and opposite directions in terms of velocities.

****

"Let's review a bit here. What is motion?"

****

Change in position

****

"Good. OK, how is the speed of an object calculated?"

****

Speed = distance/time

****

"Fine. Finally, what quantity gives both the speed and the direction of an object?"

****

Velocity

****

"Good. (Student), please read the first paragraph under `Changes in Velocity' on p. 539."

****

Student reads.

****

"Thank you. Now, (Student), I want you to read about acceleration and deceleration. Would you read the next paragraph, please?"

****

Student reads. Write 'acceleration = change in velocity/time' on the overhead transparency.

****

"Thank you. Let's take a look at the last part of the paragraph there. How do we measure change in velocity?"

****

In kilometers per hour or meters per second

****

"Good. Now, how do we measure time?"

****

In hours or seconds

****

"That's right. So, when we measure acceleration we measure in kilometers per hour per hour or in meters per second per second."

****

Put "km/hr/hr and "m/sec/sec" on the transparency.

****

"Let's look at an example. Read the last paragraph on p. 539 silently while I read it aloud."

****

Read paragraph.

****

"So, acceleration is the rate of change in velocity. When an object slows down, we call this deceleration. It is also called negative acceleration because it is a decrease in velocity. You use the same formula to find deceleration as you do to determine acceleration.

"When you are talking about circular motion, acceleration is a bit different. (Student), read the two paragraphs under the heading Circular Motion."

****

Student reads.

****

"Thank you. The word velocity is really important here. What are the two parts of velocity?"

****

Speed and direction

****

"That's right, speed and direction. So even if an object is going at a constant speed, if it isn't going in the same direction, it is accelerating. Therefore, objects going in circles are actually accelerating even if they are moving at a constant speed.

"Let's look at the questions at the top of p. 541 as a brief review. What is acceleration?"

****

Rate of change of velocity

****

"Good. What is another name for negative acceleration?"

****

Deceleration

****

"That's right. Why is an object traveling in a circular path at constant speed accelerating?"

****

It's changing direction, so it's velocity is changing, and therefore it's accelerating.

****

"Thus far we have been talking about force, newtons, mass, weight, distance, speed, and velocity. Now I'd like to do an exercise dealing with how much you'd weigh on

Earth, Mars, Jupiter, and the moon. Get out a pencil while I pass the sheets out."

****

Pass out the activity sheets.

****

"Now, let's take a look at this activity sheet. I want you to read the directions silently to yourself while I read them aloud."

****

Read directions.

****

"To make this easier, let's pretend each of you has a mass of 50 kg. Remember, if you multiply your mass by the number of newtons per kilogram, you can figure your weight at any given place in our Universe. Let's figure the weight of a 50 kg. mass here on Earth together. On Earth there are 9.8 newtons per kilogram. So, a mass of 50 kg. would weigh 9.8 times 50 kg. or how many newtons?"

****

490 N.

****

"That's right, 490 N. Now, on your own, I want you to determine what your weight would be on the moon, Mars, and Jupiter. The number of newtons per kilogram are given on the activity sheet for you."

****

Allow the students to complete the activity sheet. Wander around the room, monitoring their work, and helping as necessary. Just before class is over, tell them good-bye and tell them they will be continuing to study about motion the next day. If there is time, review the major concepts.

****

Lesson Three: Newton's First Law of Motion

Objectives: The student will be able to:

1) State Newton's First Law of Motion
2) Define inertia
3) Give examples of inertia in his/her life
4) State what an object will do when an outside force changes its motion

Activities: Review concepts and definitions from previous day's discussion. Complete a word scramble puzzle on motion concepts. Complete an activity to determine the velocity of a car. State, read about, and discuss Newton's First Law of Motion, including friction, forces, and inertia. Watch a demonstration about inertia and discuss it. Conduct and then discuss an investigation about Newton's First Law of Motion. Conduct a review of all the concepts and vocabulary associated with Newton's First Law of Motion.

Materials:

1) Photocopied excerpts from text
2) Blank overhead transparency and pens
4) Overhead projector
5) Transparency with vocabulary words

6) Book attached to a dowel rod with a string hanging down from it that has a large magic marker attached to it

7) Activity sheet on Newton's First Law of Motion from Prentice-Hall's Teacher's Resource Book

8) Word scramble on motion concepts

Time: 90 minutes

Script: "Yesterday we were talking about motion and velocity. Who can tell me the difference between these two terms?"

****

Motion is a change in position, and it involves distance and speed. Velocity is a measure of motion that involves not only distance and speed, but direction as well. Point to the definitions of motion, distance, speed, velocity, and the formula s = d/t on overhead transparency.

****

"Good. Now let's think about acceleration. What is acceleration?"

****

Rate of change of velocity

****

"Good. How do we figure the acceleration of an object?"

****

Acceleration of an object is equal to its change in velocity divided by the time during which the change occurs. Point to the definition for acceleration and the formula a = cv/t on overhead transparency.

****

"Very good. Now, let's review about circular motion. Who can tell me why circular motion always involves acceleration even if the object maintains a constant speed?"

****

Circular motion involves acceleration because the object is constantly changing direction.

****

"Very good. Remember, acceleration involves change in velocity, and velocity is determined by both the speed and direction of an object. I think you understand that well."

"Look at the activity at the top of p. 541. Let's determine the velocity for that car. (Student), what is the formula for determining acceleration?"

****

a = cv/d

****

"Good. OK, what is the change in velocity here?"

****

32 km/hr

****

"Right. And what is the time?"

****

8 seconds

****

"OK, so what is the acceleration?"

****

32 km/hr / 8 sec = 4 km/hr/sec

****

"That's right; the car's acceleration--its change in velocity divided by the time it took for this to happen--is 4 km/hr/sec. This means that every second the car slowed down an average of 4 km/hr.

"Now I'd like to introduce Newton's First Law of Motion. The work you've been doing up until now has been leading up to this. Who remembers who Sir Isaac Newton was?"

****

A famous scientist who studied motion

****

"That's right. Newton added a lot to what we know about motion. His work was very important because so much of what happens in our world involves motion."

"Newton's First Law of Motion states that an object at rest tends to stay at rest, and that an object in motion tends to stay in motion in a straight line at a constant velocity unless acted upon by an unequal force."

****

Write the law on the blank overhead transparency.

****

"(Student), I'd like you to read the first paragraph on p. 541."

****

Student reads.

****

"Thank you. Now, I'd like for all of you to read the rest of this information sheet silently to yourselves."

****

Allow the students three minutes to read.

****

"OK, let's talk about what you just read. How many of you knew that if it weren't for friction and other forces, when you rode your bicycles you would be able to go on forever? Raise your hands, and let me see."

****

Pause, survey group

****

"It's hard to imagine, but scientists in frictionless environments have shown this to be true. What is inertia?"

****

The tendency for objects to continue what they are doing. Write the definition for inertia on the blank overhead transparency.

****

"That's correct. Because inertia is what Newton's First Law of Motion is all about, it is also called the Law of Inertia.

"Let's think about inertia for a minute. Think about riding in a car. What happens when someone puts on the brakes quickly when you're riding in a car?"

****

You continue to go forward while the car slows.

****

"What would happen if you were riding your bike down the street, and you got your backpack caught in the spokes?"

****

The bike would stop, and you would go forward, probably falling off your bike.

****

"That would hurt, wouldn't it? Remember, the bike, with you on it, will keep moving at the same speed and in the same direction unless acted upon by an outside force. What is the outside force in the case of the bike and the backpack?"

****

The backpack

****

"That's right, the bike stops because of the backpack, but you would keep going at the same speed and the same direction and fall off the bike. Actually, there is another force at work, too. What is it?"

****

Friction

****

"That's right. The bike would eventually slow down due to friction as well.

"This is baseball season, so let's take a baseball for example. If a baseball is lying on a baseball diamond, it will continue to lie there until an outside force moves it. It is basically lazy and won't move unless it has to. What are some of the forces that might move it?"

****

Accept any reasonable answer such as a person, the wind, or an animal.

****

"OK, good. Now, what if that ball is moving? What will it do?"

****

Keep on moving

****

"That's right; it will continue to move at a constant speed in a straight line unless what?"

****

Acted on by some outside force

****

"Good! It takes an outside force to stop the ball. What might some of those outside forces be that would change the speed or direction of this baseball?"

****

Accept any reasonable answer, including such forces as friction with the air, gravity, or being caught by someone.

****

"What if the baseball hit something? What would happen then?"

****

It would be slowed down considerably and would richochet off in another direction.

****

"Let's look at an example demonstrating inertia. (Student), read what it says at the top of p. 542."

****

Student reads.

****

"Let's try the demonstration to see what happens."

****

Do the demonstration. Discuss. The string breaks in different places because of the different force that is placed on the string. The sudden, quick jerk acts as an acceleration force at the point of the stress while the force of acceleration of slow pulling on the rod places stress along the string more evenly. The added weight of the book causes the string to break above where the string is attached to the book.

****

"Now to work with some of the concepts you've learned so far, I want you to do this word scramble puzzle using motion words. The words all deal with the concepts we've been talking about these last few days. You'll have 10 minutes to finish."

****

Pass out sheets. Allow about 10 minutes, then collect the puzzles. Answer any questions about the puzzle.

****

"Now I'd like all of you to do an investigation of Newton's First Law of Motion. I'll pass out the investigation sheet. While I'm doing this, I want you to get a partner to work with."

****

Pass out investigation sheet entitled "Newton's First Law of Motion." Read the directions aloud to the students while they read silently. Pass out a small rubber ball to each group. Tell the students to do the investigation together, with one person doing the ball tossing, and the other observing and recording. Walk around and monitor the groups as they perform the investigation. Give the groups about 20-25 minutes to complete the activity. At the end of this time, have them get back in their seats.

****

"OK, let's discuss what you've learned while you investigated the Law of Inertia. Let's do number 1. (Student), when you threw the ball straight up in the air, did it land in your hand?"

****

Yes

****

"All right. Now, (Student), when you were walking at a constant speed, where did the ball land?"

****

In the hand

****

"Good. Now, (Student), what happened when you did the same thing in number 3 but stopped immediately?"

****

Ball landed in front of person

****

"Good; I see you conducted this investigation carefully. What about number 4 where you ran ahead, (Student)?"

****

Ball landed in back of person

****

"All right now what about number 5; when you made a sharp 90° turn to the right, what did the ball do?"

****

Ball landed behind and to the left

****

"Good. Now for the big question, where would it land if you jumped up in a jumbo jet that was moving at 600 m.p.h.?"

****

In the same spot from which you jumped

****

"Very good. How did you figure that out?"

****

Allow students to give their reasoning. Make sure they understand that because both the plane and the person are moving forward at the same speed and because there is no outside force changing the forward motion, both the plane and the person will continue to move forward at the same rate despite the person jumping up. The vertical motion does not alter the horizontal motion of the person.

****

"Before we finish today, I want to remind you that you'll be having a quiz over Newton's First Law of Motion tomorrow. The questions will be multiple choice, true-false, and which word doesn't belong? Be sure to study your information sheets, your notes, and your vocabulary words. Do you have any questions about Newton's First Law of Motion?

****

Answer any questions the students may have. If there is still time in the class period, pose some review questions over the major concepts.

****

MOTION
VOCABULARY #1

1. **FORCE** = a push or pull exerted on an object
2. **NEWTON** = metric unit of force
3. **MASS** = quantity of matter in an object
4. **WEIGHT** = amount of force gravity exerts on an object
5. **SPRING BALANCE** = instrument used to measure force
6. **FRICTION** = force that opposes the horizontal movement of an object

Name ______________________ Class ________________ Date ____________

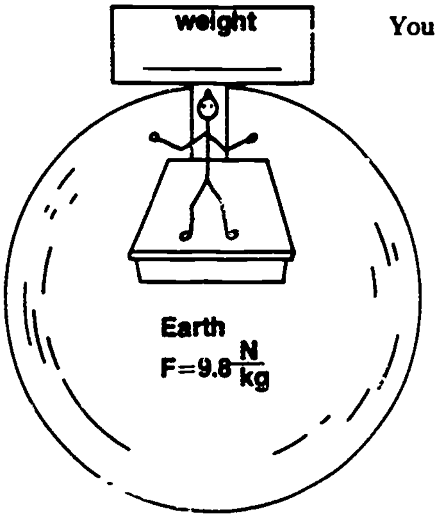
Chapter 22
Force and Work

How Much Do You Weigh?

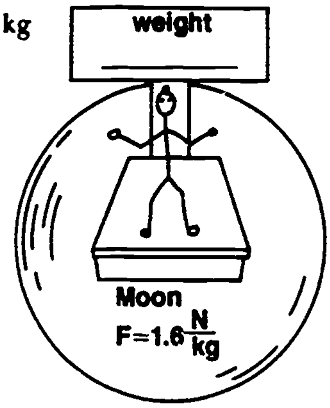
Weight is a measure of the force of gravity on an object. The force of gravity is not a constant value in the universe. The force of gravity on the surface of the planet Jupiter is more than 2½ times the force of gravity on the surface of Earth. The moon's gravitational force is only about 1/6 of Earth's.

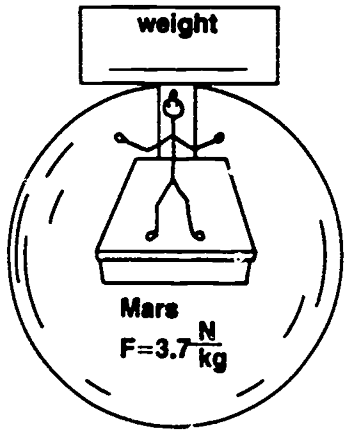
The unit of weight is the newton, N. Weight in newtons is calculated by multiplying the mass of an object in kilograms by the number of newtons per kilogram. On Earth there are 9.8 newtons per kilogram. A mass of 100 kg would weigh 100 kg × 9.8 N/kg = 980 N.

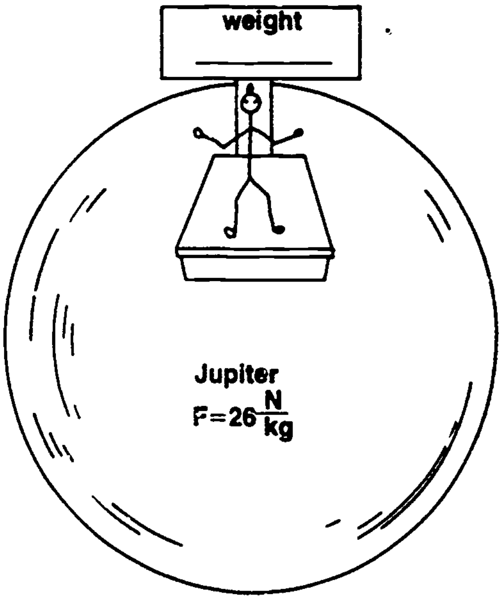
Calculate your weight in newtons on Earth, the moon, Mars, and Jupiter. Place your answers in the blank space on the appropriate scales. The newtons per kilogram on each planet are listed. If you do not know your mass in kilograms, divide your mass in pounds by 2.2. For example, if your mass is 110 pounds, your mass is 110 ÷ 2.2 = 50 kg.



Your mass ________ kg







MOTION VOCABULARY #2

1. **MOTION** = change in position

2. **DISTANCE** = how far an object has moved

3. **SPEED** = distance traveled in a particular period of time
   s = d/t

4. **VELOCITY** = speed and direction of an object

5. **ACCELERATION** = rate of change in velocity
   a = cv/t

Name ______________________ Class ______________ Date ____________

Chapter 23
Motion and Gravity

Newton's First Law of Motion

Newton's first law of motion states that an object in motion will continue to move at constant speed in a straight line. Only an outside force can change the speed or direction. If the object is at rest, it will remain at rest, unless an outside force is exerted on it.

Suppose you are standing in the aisle of a jumbo jet parked at its terminal. You jump straight up. Where will you land? That is an easy question to answer. You will land in the same place from which you jumped. But now suppose the jet is moving at a speed of 600 km/hr. You jump straight up again. Where will you land? Try this activity and see if you can answer the question correctly.

1. While standing still, throw a small, rubber ball straight up about 2 or 3 meters high. Does it land in your hand?
2. Now walk at a constant speed and throw the ball straight up. Where does the ball land?
3. Continue walking at a constant speed. This time, stop instantly just after you release the ball upward. Where does the ball land?
4. Continue walking at a constant speed. Just after you release the ball upward, break into a run. Where does the ball land?
5. Continue walking at a constant speed. Just after you release the ball upward, make a sharp right turn. Where does the ball land?
6. Where would you land on the jumbo jet that is moving at 600 km/hr?

MOTION WORD SCRAMBLE

Fill in the blanks in the paragraphs below with the correct words by unscrambling the letters to the left of the blanks.

TOMINO ________________ is a change in position. The change in position of an object occurs in a certain amount of time, during which the object moves a certain STANDICE ________________. This is called the object's PEDES ________________. If the quantity distance divided by time also includes the directin of motion, then the object's TILYVOCE ________________ is being measured. If an object speed up or changes its direction, the object undergoes LEACRANICOTE ________________.

The principle of IRATINE ________________ describes the tendency of an object in motion to continue in that state of motion unless acted upon by an outside force. Newton stated this in his TIFSRONFIMATLOWO ________________________. In addition, Newton proposed that there is an attractive force between any two objects anyplace in the universe. He called this force TRIVYAG ________________.

A CEROF ________________ is a push or a pull. The pull gravity exerts on an object is its GITHWE ________________, while the quantity of matter in an object is its SAMS ________________. The metric measure of force is the TWENON ________________ and the LASPANNIBCERG ________________ measures the metric unit of force.

APPENDIX D

ASSESSMENT OF CLASS FORM

ASSESSMENT OF CLASS

Please rate your 6th grade Academically Gifted class on the form below. Put a circle around the response that best describes your class in general. Put any comment you have about the statement in the "Comments" section after each question.

The ratings are as follows:

1--Rarely, if ever
2--Occasionally
3--Often
4--Almost always

****

In general, are/do the students in this class:

1. Motivated to achieve well in school? 1 2 3 4

Comments:

2. Motivated to achieve well in topics having to do with science? 1 2 3 4

Comments:

3. Interested in school? 1 2 3 4

Comments:

4. Interested in science topics? 1 2 3 4

Comments:

5. Achieve well academically in school? 1 2 3 4

Comments:

6. Achieve well academically in science? 1 2 3 4

Comments:

7. Academically capable? 1 2 3 4

Comments:

8. Academically capable in science? 1 2 3 4

Comments:

9. Similar in their academic abilities? 1 2 3 4

Comments:

10. Similar in their academic abilities in science? 1 2 3 4

Comments:

11. Creative? 1 2 3 4

Comments:

12. Well-behaved? 1 2 3 4

Comments:

Your Name ______________________ Class ______________

APPENDIX F

ATTITUDE SURVEY

Name ______________________________

ATTITUDE SURVEY

Please respond to the following statements honestly. Your responses will not affect your test grade.

Rate your feelings about the following statements. Put a circle around the number that best describes your feelings.

The ratings are as follows:

1--Strongly Disagree
2--Disagree
3--Agree
4--Strongly Agree

****

1. This unit on motion was interesting. 1 2 3 4
2. I enjoyed studying this unit on motion. 1 2 3 4
3. I would like to study Newton's other laws of motion. 1 2 3 4
4. I would like to study other topics similar to this one. 1 2 3 4
5. I would like to learn more about physics. 1 2 3 4
6. I enjoyed the activities we did in this unit. 1 2 3 4
7. Even if I didn't have to take science in school next year, I would still sign up to take it. 1 2 3 4
8. Science is important for people to know about. 1 2 3 4
9. Knowing science can help you understand other things. 1 2 3 4
10. Knowing what I know now about the unit on motion I just completed, if I had to do it all over again, I would want to study motion in a similar way. 1 2 3 4

APPENDIX F

ACHIEVEMENT TEST AND ANSWER KEY

Answer Key

NEWTON'S FIRST LAW OF MOTION

<u>Multiple Choice</u>. Darken in your answer sheet with the number of the statement that best answers the question.

1. Which of the following is the metric unit used to measure force?

   1. Gram
   2. Liter
   3. Meter
   [✓ 4.] Newton

2. Which of the following is the best example of "velocity" as the term is used by scientists?

   1. A car traveling 40 kilometers per hour on an oval track
   [✓ 2.] A car traveling 50 kilometers per hour and heading straight west
   3. A car going from 50 kilometers to 60 kilometers per hour in 10 seconds
   4. A car with a mass of 1,000 kilograms traveling at 70 kilometers per hour

3. Which of the following is the average speed of a runner who completes a 1 kilometer (1 km) race in 4 minutes?

   1. 0.25 meters per second
   2. 0.25 meters per minute
   3. 250 meters per second
   [✓ 4.] 250 meters per minute

4. A pair of dice is hanging from the mirror of a car. Which of the following best describes what will happen to the dice as the speed of the car changes while traveling down a level road?

   [✓ 1.] The dice will swing toward the rear when the car speeds up and toward the front as the car slows down.
   2. The dice will swing toward the front when the car speeds up and toward the rear when the car slows down.
   3. The dice will swing toward the front and then return so the string is vertical whenever the car speeds up or slows down.
   4. Because of the force of gravity on the dice, they will not move forward or backward as the car speeds up or slows down.

5. What is the average acceleration of a car if it speeds up from 10 kilometers per hour to 30 kilometers per hour in 10 seconds?

   [✓ 1.] 2 kilometers per hour per second
   2. 3 kilometers per hour per second
   3. 20 kilometers per hour
   4. 20 kilometers per hour per second

6. What is the average speed of a bicycle rider who travels 5 kilometers (5,000 meters) in 10 minutes?

   1. 0.5 meters per second
   2. 0.5 meters per minute
   3. 500 meters per second
   [✓ 4.] 500 meters per minute

7. Which of the following is the best answer when a pilot is asked by the control tower to report the airplane's velocity?

   1. "I just went from 200 kilometers per hour to 220 kilometers per hour in the last 3 minutes."
   [✓ 2.] "I'm going 240 kilometers per hour and going due north."
   3. "I'm going 250 kilometers per hour."
   4. "I'm going 260 kilometers an hour with a total mass of 1500 kilograms."

8. A passenger in the backseat of a car holds a large round-bottomed bowl containing a ball so that the top of the bowl is level with the road. Which of the following best describes what will happen to the ball as the speed of the car changes as it travels down a level road?

   1. Because of the force of gravity pulling down on the ball, it will not move relative to the bowl as the car speeds up or slows down.
   2. The ball will move toward the front as the car speeds up and toward the front as the car slows down.
   [✓ 3.] The ball will move toward the rear as the car speeds up and toward the front as the car slows down.
   4. The ball will move toward the front of the bowl, and then return to the lowest point in the bowl when the car either speeds up or slows down.

9. What is the average acceleration of a car that slows down from 60 kilometers per hour to 20 kilometers per hour in 20 seconds?

   [✓ 1.] 2 kilometers per hour per second
   2. 3 kilometers per hour per second
   3. 40 kilometers per hour
   4. 40 kilometers per hour per second

10. Which of the following best describes what will happen to the gravitational attraction between Planet A and Planet B if the mass of one of the planets is doubled?

1. The attraction would be one-fourth as much.
2. The attraction would be one-half as much.
[✓ 3.] The attraction would be doubled.
4. The attraction would be four times as much.

11. Which of the following best describes what will happen to the weight of a person standing on a bathroom scales in an elevator?

[✓ 1.] The weight shown on the scales will decrease as the elevator starts downward and increase as the elevator starts upward.
2. The weight shown on the scales will decrease as the elevator starts upward and increase as the elevator starts downward.
3. The weight shown on the scales will increase whenever the elevator starts to move either upward or downward.
4. The weight shown on the scales will not change because a person's weight does not change during a period of time as short as that involved in an elevator going up or down.

12. What law states that an object at rest tends to remain at rest unless acted upon by a force?

[✓ 1.] First Law of Motion
2. Second Law of Motion
3. Third Law of Motion
4. Law of Universal Gravitation

13. A change in an object's location or position is called

[✓ 1.] Motion
2. Force
3. Energy
4. Momentum

14. If an object slows down, it

[✓ 1.] Accelerates
2. Stops
3. Increases momentum
4. Changes its mass

15\. The speed of an object that moves 50 kilometers in 5 hours is

1. 0.1 hr/km
2. 0.1 km/hr
3. 10 hr/km
[✓ 4.] 10 km/hr

16\. What is the acceleration of an object moving at a constant velocity of 10 km/hr east?

[✓ 1.] 0
2. 60 km/hr east
3. 98 km/hr west
4. Cannot be determined with the information given

17\. The scientific name for a push or pull is

[✓ 1.] Force
2. Energy
3. Power
4. Mechanical advantage

18\. Force is measured in

1. Joules
[✓ 2.] Newtons
3. Watts
4. Grams

19\. Lubricants are used to reduce

1. Buoyancy
2. Fluid friction
3. Rolling friction
[✓ 4.] Sliding friction

20\. Friction is a form of

1. Energy
2. Work
3. Power
[✓ 4.] Force

21\. What law or principle states that there is an attraction force that acts between all objects?

1. Archimedes' Principle
2. Bernouilli's Principle
[✓ 3.] Law of Universal Gravitation
4. Newton's First Law of Motion

22. A device that measures force is a

[✓ 1.] Spring balance
2. Triple-beam balance
3. Double-pan balance
4. Graduated cyliner

23. Which of the following expresses velocity?

1. 20 km
2. 20 km/hr
3. 20 km/hr/hr
[✓ 4.] 20 km/hr north

24. Speed

1. Gives no information about distance covered per unit time
[✓ 2.] Gives no information about direction
3. Is the same thing as velocity
4. Is the same thing as acceleration

25. Which of Newton's laws states that an object at rest tends to stay at rest?

[✓ 1.] First Law of Motion
2. Second Law of Motion
3. Third Law of Motion
4. Law of Universal Gravitation

26. The tendency of objects to continue to move at the velocity at which they are already moving is called

1. Mechanical advantage
2. Friction
3. Thrust
[✓ 4.] Inertia

27. What is the speed of an object that moves 20 km in an easterly direction in 4 hours?

[✓ 1.] 5 km/hr
2. 5 km/hr E
3. 5 km/hr west
4. 5 km

28. Newton's First Law of Motion states that a force is needed to change

1. Kilometers
[✓ 2.] The direction of a moving object
3. Gravity
4. Weightlessness

29. A measure of how fast an object moves is

1. Force
[✓ 2.] Speed
3. Motion
4. Gravity

30. The three factors involved in describing motion are

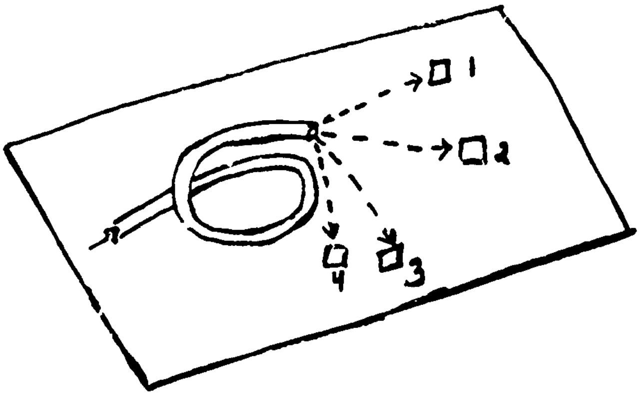
1. Distance, time, direction
[✓ 2.] Distance, time, speed
3. Time, speed, direction
4. Velocity, acceleration, direction

31. Which of the following best describes what will happen to the weight of a person standing on a bathroom scales inside the car of a large moving Ferris wheel?

1. The weight shown on the scales will decrease as the car starts moving upward and increase as the car goes over the top and starts downward.
2. The weight shown on the scales will decrease as the car starts to turn regardless of the car's position and will increase when the car slows down.
[✓ 3.] The weight shown on the scales will increase as the car starts to move upward and decrease as the car goes over the top and starts downward.
4. The weight shown on the scales will not change because a person's weight does not change during a period of time as short as that involved in making a few revolutions of the Ferris wheel.

32. In the diagram below, which of the targets will be hit by the ball when it comes out of the coiled tube?

1. Target 1
[✓ 2.] Target 2
3. Target 3
4. Target 4



33. Four players try their hand at rolling a ball through the curved pathway shown in the diagram below. To win, the ball cannot touch the walls of the pathway. Which player should win if the balls are placed in motion in the manner shown by the dotted lines and released at the points indicated with the arrow heads?

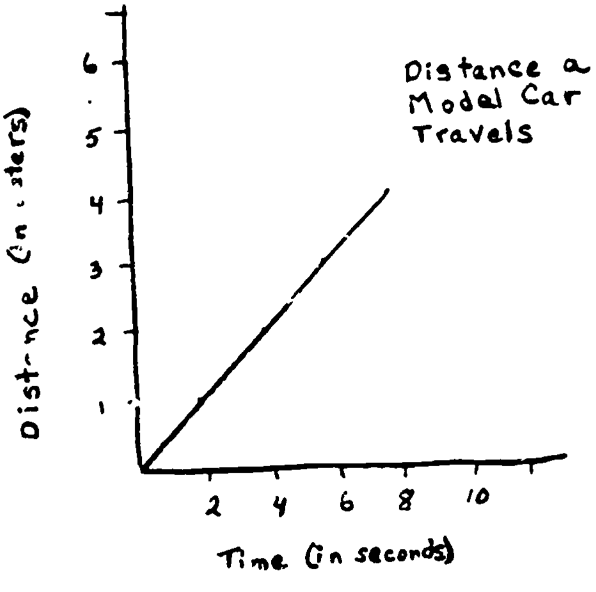
1. Player 1
[✓ 2.] Player 2
3. Player 3
4. Player 4

The graph below represents the distance a model car traveled in a straight line in a given period of time. Based on the information given, answer the following questions.

34. Was the car accelerating? (Darken "1" for yes and "2" for [✓ no.])

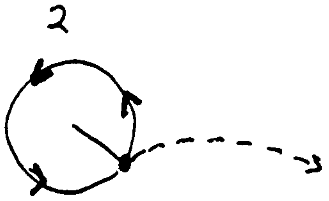
35. If the present trends continue, how far will the car travel in 12 seconds?

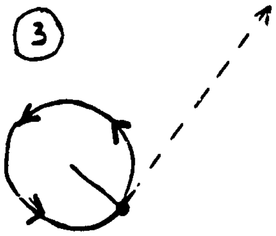
1. 4 m
2. 5 m
[✓ 3.] 6 m
4. 7 m



36. Look at the diagrams below. Imagine that someone has a metal ball attached to a string and is twirling it at high speed in a circle above his head. In the diagrams you are looking down on the ball. The circle shows the path followed by the ball, and the arrows show the direction in which it is moving. The line from the center of the circle to the ball is the string. Assume that when the ball is at the point shown in the diagram, the string breaks where it is attached to the ball.

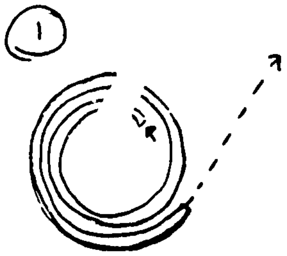
Look at the four possible solutions as to the direction the ball would go when the string breaks. Darken in the number of the picture that best represents the direction the ball would go.

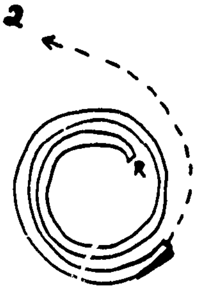


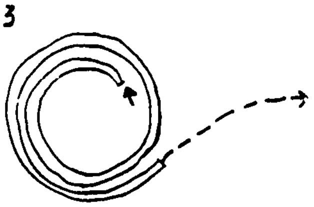


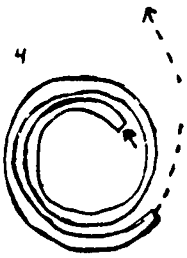
37. The diagrams below show a thin curved metal tube. You are looking down on the tube. In other words, the tube is lying flat. A metal ball is put into the end of the tube indicated by the arrow and is shot out of the other end of the tube at high speed.

Look at the four possible solutions as to where the ball would go when shot from the tube. Darken in the number of the diagram that best represents the path you think the ball will take when exiting from the tube.









True or False. If a statement if true, darken in the "1" on your answer sheet. If it is false, darken the "2".

T 38. Friction is a force that opposes the motion of an object.

F 39. Weight is the same as mass and can be measured in kilograms.

F 40. The quantity that expresses speed and direction is called acceleration.

T 41. Weight is the amount of force the earth's gravity exerts on an object.

F 42. Gravitational force is exerted only by very large objects such as the earth.

T 43. A single force cannot exist by itself.

F 44. An object whose velocity is increasing is decelerating.

F 45. A force is not required to slow down a moving object; the object will slow down by itself.

T 46. In a vacuum, all objects will fall with the same acceleration.

F 47. The newton is a unit of energy.

T 48. Acceleration is always measured as distance/time/time.

F 49. Speed is measured as distance per unit of time with a direction stated.

T 50. Inertia is changed by a force.

F 51. Weight is measured by the quantity of matter in an object.

T 52. If an object speeds up or changes direction, it is accelerating.

F 53. The metric unit of force is the kilogram.

T 54. The First Law of Motion is also known as the Law of Inertia

<u>One Doesn't Belong</u>. Three of the following words having to do with motion belong together and one doesn't. Darken in the number of the word that doesn't belong.

55. 1. buoyancy, 2. gravity, 3. friction, [✓ 4.] newton

56. 1. newton, [✓ 2.] density, 3. weight, 4. force

57. 1. inertia, 2. motion, 3. rest, [✓ 4.] power

58. [✓ 1.] velocity, 2. air resistance, 3. friction, 4. gravity

59. 1. acceleration, 2. speed, [✓ 3.] newton, 4. velocity

60. [✓ 1.] Direction, 2. distance, 3. speed, 4. time

APPENDIX G

LETTERS OF VALIDATION

CHAPEL HILL-CARRBORO CITY SCHOOLS
LINCOLN CENTER, MERRITT MILL ROAD
CHAPEL HILL, NORTH CAROLINA 27514
Telephone: (919) 967-8211

GERRY HOUSE, Superintendent

MICHAEL RADZ, Assistant Superintendent
for Instructional Services
SHEILA [illegible]TWEISER, Assistant Superintendent
for Support Services

May 28, 1987

Dear Committee:

I am a certified trainer affiliated with Excel, Inc., a management consulting firm founded by Dr. Bernice McCarthy, the developer of the 4MAT model. In this capacity I have given numerous presentations at national and state conferences and have conducted workshops for local school districts.

At her request, I reviewed the 4MAT unit designed by Patricia Bowers. Specifically, I "blindly" sorted the eight activities so as to make a judgment as to the step on the 4MAT circle that was appropriate. It is my assessment that these activities did in fact coincide with the steps outlined in the script prepared by Ms. Bowers. Finally, the activities provided for the "traditional" unit, were what I would classify as being largely of the left mode type.

It is my opinion that this aspect of the study is a legitimate 4MAT unit of instruction consistent with the criteria used by Excel, Inc.

Sincerely,

Michael A. Radz

Michael A. Radz
Assistant Superintendent
for Instruction

MAR:pg

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

School of Education
Division of
Teaching and Learning

The University of North Carolina at Chapel Hill
Peabody Hall 037 A
Chapel Hill, NC 27514

April 7, 1987

Ms. Patricia Bowers
600 Emory Drive
Chapel Hill, NC 27514

Dear Pat:

This letter is to confirm that the 4MAT lesson plans you have prepared for use in your research are consistent with the guidelines established by Dr. Bernice McCarthy in the 4MAT Model, and that the lesson plans you prepared for the control group are left mode lessons.

After reviewing the lesson plans designed for the experimental group, I sorted the lessons into the eight-step 4MAT cycle. I determined that the lesson plans were representative of the 4MAT Model. I then examined the lesson plans developed for the control group and agree that they are left mode lessons.

As an EXCEL Associate, I want to encourage you in your research efforts. Dr. McCarthy and other EXCEL Associates are looking forward to hearing about the results of your study.

Best wishes,

Rhonda M. Wilkerson

Rhonda M. Wilkerson, Ph.D.
Visiting Assistant Professor

RMW/chw

RESEARCH TRIANGLE INSTITUTE

Center for Educational Studies

May 8, 1987

Mrs. Patricia Bowers
Science and Mathematics Coordinator
Chapel Hill-Carrboro City Schools
Lincoln Center
Merritt Mill Road
Chapel Hill, North Carolina

Dear Mrs. Bowers:

I have reviewed your "4MAT SYSTEM LESSON PLANS" and the accompanying concept presentation materials, "Newton's First Law of Motion". These materials accurately and clearly present the concepts and vocabulary required to study the first law of motion.

I am very pleased that you have chosen to adapt materials from the Sohio *Workshops in Newtonian Mechanics* prepared by Research Triangle Institute's Center for Educational Studies for part of your doctoral research. We would greatly appreciate the opportunity to review your findings when your dissertation is completed.

If I may be of further service, please feel free to contact me again.

Yours truly,

Jack E. Gartrell, Jr.
Educational Analist

Post Office Box 12194 Research Triangle Park, North Carolina 27709 Telephone: 919 541-6000

Instructions to the Reviewer:

Please read the enclosed information sheets and accompanying activities on Newton's First Law [illegible]. Then read the script, "4MAT Approach Lesson Plans [illegible] When you have finished, please answer the questions below. Thank you very much.

Did the information sheet, "Newton's First Law of Motion," accurately represent the science concepts associated with Newton's First Law of Motion?

(yes or no) yes

Did the "4MAT Approach Lesson Plans" accurately and completely reflect the concepts on Newton's First Law of Motion found in the information sheet you reviewed?

(yes or no) yes

Was there any information included that was not a part of the information sheets and accompanying activities?

(yes or no) no

Comments:

Signed Patricia A. Hicks

Date 6-18-87

Instructions to Reviewer:

Please read the enclosed text excerpts and accompanying activities on Newton's First Law of Motion in Unit 6, Chapter 1 and 2 of Prentice-Hall's General Science, A Voyage of Discovery. Then read the script, "Textbook Approach Lesson Plans." When you have finished, please answer the questions below. Thank you very much.

Did the "Textbook Approach Lesson Plans" accurately and completely reflect the concepts on Newton's First Law of Motion found in the text excerpts and Teacher's Resource Book you reviewed?

(yes or no) Yes

Was there any information included that was not included in the text and accompanying activities?

(yes or no) No

Comments: The lesson plans followed the text extremely well – closely, anyway. Sometimes it was a detrment to follow the text. The book + String experiment was a poor one to demonstrate acceleration.

The last activity which gave the students a better understanding of Newton's First Law of Motion was not included in the text, but could not be considered as adding more information. It merely broadened the understanding of the information given in the text

signed Sara Parker Enriquez

date June 17 1987

Instructions to Reviewer:

Please read the enclosed text excerpts and accompanying activities on Newton's First Law of Motion in Unit 6, Chapter 1 and 2 of Prentice-Hall's General Science. A Voyage of Discovery. Then read the script, "Textbook Approach Lesson Plans." When you have finished, pleasw answer the questions below. Thank you very much.

Did the "Textbook Approach Lesson Plans" accurately and completely reflect the concepts on Newton's First Law of Motion found in the text excerpts and Teacher's Resource Book you reviewed?

(yes or no) yes

Was there any information included that was not included in the text and accompanying activities?

(yes or no) no

Comments:

signed Patricia A. Hicks

date 6-18-87