THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

RELATIONSHIPS AMONG REASONING ABILITY, MEANINGFUL LEARNING, AND COMPUTER-BASED INSTRUCTION ON STUDENTS' UNDERSTANDING OF NEWTON'S LAWS.

A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

Doctor of Philosophy

By

HAMID H. BAHARESTANI

Norman, Oklahoma

1999

UMI Number: 9935529

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

RELATIONSHIPS AMONG REASONING ABILITY, MEANINGFUL LEARNING, AND COMPUTER-BASED INSTRUCTION ON STUDENTS' UNDERSTANDING OF NEWTON'S LAWS.

A Dissertation APPROVED FOR THE DEPARTMENT OF INSTRUCTIONAL LEADERSHIP AND ACADEMIC CURRICULUM

By

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and admiration to a number of people who have contributed to this research effort.

Dr. Michael R. Abraham (Committee Chairman) for his patience, tireless hours of reading, guidance, leadership, and for providing valuable suggestions on the animation part of the CBI lesson during the course of this study. Dr. Edmund A. Marek (Committee Co-chairman) for providing me with a better view of science education and its implications for public school, advice, support, and guidance throughout my graduate studies. Dr. Jay C. Smith for serving on my Ph.D. advisory committee and providing me with the role model of a real thinker. I learned a lot in his class. He has given me a great deal of advice and very kind assistance throughout my coursework. And he fought for me when I needed him. I also want to thank Dr. Richard C. Henry for serving on my Ph.D. advisory committee and for providing advice, guidance, and for taking the time to review my CBI lesson program and to make valuable comments and suggestions. In addition, I would like to thank Dr. Loraine A. Dunn for her assistance, comments, suggestions, and for serving on my Ph.D. advisory committee.

Special thanks also goes to Dr. Ann M. L. Cavallo for her truthful support, model of a scholar, and for being the first person introduce me to the learning cycle, and to made me think about this field of research, and the hands-on learning procedure. She truly served as a model for my graduate school successes.

I am very grateful to Dr. Michael G. Strauss for allowing me to conduct this research project in his Physics for Life Science class. Even though he was not on my advisory committee, he was always there when I turned to him for consultation on the timing of the collection of the data. I also thank both his teaching assistants, Mrs. Kate McDonald and Dean Richardson for their continuous support in collecting data in their discussion sections of class.

Thanks to Dr. Bruce E. Mason for running the CTI, CTGI, and CBI lesson program on the Physics Computer Lab at the University of Oklahoma to make sure that it worked well and on schedule.

My sincere appreciation goes to FAA (system support branch) manger Mrs. Gwen Sawyer who allowed me to assemble some components of the programming part of the CTI, CTGI, and CBI lessons, especially the audio parts of the program, in the FAA facilities. Others who helped me included: Kay Chisolm, Laurie St. John, Mecca Morgan for the audio, Jim Compton (OU team leader), Kenny Goodwin for the CBI Template, Mr. Bill Fix, Todd Hubbard for their review of the lesson, Steve Harmen and the OU writing center for the possible English grammar errors of the proposal, Carol Slate, and Pat Thompson for the graphics, and finally Ron Franks and Laurie St. John for the animation of the CBI lesson.

My thanks to the faculty and staff of the Instructional Leadership and Academic Curriculum of the College of Education for their support as well as Mr. Todd Hubbard for English grammar and content of the final draft of this dissertation.

Finally, I would like to thank my family, friends, and my wife. I am especially grateful to my wife, Mahin Taheri, for her understanding and support in my research and in our family life. It was their love, their encouragement and support that made the completion of my Ph.D. degree possible.

TABLE OF CONTENTS

ACKNOWLEDGMENTS iv
TABLE OF CONTENTS vii
LIST OF TABLE ix
LIST OF FIGURES x
ABSTRACT xi

Chapter I: Introduction

Background of Study 1
Problem Statement 3
Significant of the study 4

Chapter II: Introduction

Current Literature Review 6
Computer and Understanding 6
Reasoning Ability 18
Meaningful Learning 23

Chapter III: Research Methodology

Research Design 29
Sampling Procedures 31
Statistical Analysis 32
Instruments 36
Force Concept Inventory 36
Test of Logical Thinking 37
Learning Approach Questionnaire 38
Computer Text Instruction 39
Computer Text-Graphic Instruction 39
Computer-Based Instruction 39

Chapter IV: Results

The TOLT 44
Research Question One 46
Research Question Two 51
Research Question Three 56

Chapter V: Discussion and Conclusions

Question One Discussion 62
Question Two Discussion 63
Question Three Discussion 65
Conclusions 66
Suggestion for Further Research 68

Reference 69

Appendices Index 79

Appendix A: Permission Letter 79

Appendix B: Physics Conceptual Questions 82

Appendix C: The Force Concept Inventory 90

Appendix D: The Learning Approach Questionnaire 102

Appendix E: The CTI Program 106

Appendix F: The CTGI Program 122

Appendix G: The CBI Program 138

Appendix H: Individual Students' TOLT Scores 154

Appendix I: Individual Students' FCI Scores 158

Appendix J: All Individual Students' TOLT Scores 171

Appendix K: Individual Students' LAQ Scores 181

LIST OF TABLES

Table

1. Descriptive Data for the TOLT 45

2. ANOVA Results for TOLT Scores in the T. Groups 46

3. Group Means on the FCI 47

4. ANOVA Results for the FCI Scores in the T. Groups 47

5. Post Hoc (Pairwise Comparison) 50

6. Univariate Analysis for the FCI Scores in the Treatment Groups VS. Concrete and Formal Reasoning Students 52

7. Descriptive Statistics for the FCI Scores in the Treatment Groups VS. Concrete and Formal Reasoning Students 53

8. Groups Comparison Concrete and Formal Reasoning Students 54

9. Univariate Analysis for the FCI Scores in the Treatment Groups VS. Rote Learning and Meaningful Learning Students 59

10. Descriptive Statistics for the FCI Scores in the Treatment Groups VS. Rote Learning and Meaningful Learning Students 60

11. Groups Comparison for the Rote Learning and Meaningful Learning Students 61

LIST OF FIGURES

Figure

1. Sample Structure According to Ethic Background 33

2. Sample Structure According to age 32

3. Computer Text Instruction Screen 41

4. Computer Text-Graphic Instruction Screen 42

5. Computer-Based Instruction Screen 43

6. Boxplot of FCI Scores 48

7. Boxplot of FCI Scores VS Concrete & Formal Learner 55

8. Boxplot of FCI Scores VS Rote & Meaningful Learner 58

ABSTRACT

The purpose of this study was to better understand the nature and extent of students' understanding of Newtonian physics. This study investigated differential effects of three different instructional treatments (computer text instruction [CTI], computer text-graphic instruction [CTGI], and computer-based instruction [CBI]). These treatments exposed areas of the subjects' lack of understanding of physics concepts that were measured by the Force Concept Inventory (FCI) to determine students' misunderstandings of Newtonian physics concepts. The sample consisted of 90 undergraduate students with non-physics majors enrolled in the physics for life science course at a comprehensive university in the Midwest. The results indicate that students who used the CBI lesson did significantly better than students using the CTGI or CTI lessons with respect to understanding Newton's laws. In addition, students who used a more meaningful learning approach did not necessarily have higher reasoning abilities.

CHAPTER 1

Introduction

Background of the Study

Empirical research relating to students' conceptual understanding of physics indicates that most students do not connect the physics of motion (i.e., Newtonian laws) with their everyday life experiences (Hestenes, Wells, & Swackhamer, 1992). Generally, it seems that students experience cognitive difficulty in grasping Newtonian physics concepts. As a result, science educators have called for a newer, deeper, more robust instructional focus with regard to physics (Linn, 1988) or a change in teaching method, which encourages deeper understanding of the subject area (Minstrell, 1989). Recent findings in child psychology suggest that children possess certain ideas about perception. These ideas typically relate to natural events children experience before they are taught physical science in a traditional school environment. A considerable gap exists between students' conceptual understanding of physics and knowledge used in problem-solving tasks (Reiner & Shauble, 1990). In addition, Haertal (1990) draws the conclusion that formal mathematical and physical knowledge—without a conceptual understanding of basic concepts and relations—does not necessarily help students solve problems.

Many instructors have realized the importance of computer-based instruction in the classroom. Consequently, numerous researchers have employed a wide variety of techniques to evaluate the overall effectiveness of computers in enhancing student classroom learning (Roblyer, Castine, & King, 1988). Interestingly, the majority of these researchers found computers quite effective for overcoming certain cognitive difficulties in the students' grasp of science concepts (Weller, 1995; Kulik & Kulik, 1991; Wise, 1989; Roblyer, Castine, & King, 1988).

In addition to instructional procedures, other factors related to student abilities and learning approaches may explain the difficulty students have with understanding physics concepts. One such factor is students' reasoning ability, ranging from pre-concrete to formal (Lawson & Thompson, 1988). Students who are capable of abstract formal reasoning can obtain a more sound understanding of abstract concepts in physics.

Another factor related to physics understanding is the students' ability to assimilate information as being meaningful or to merely ingest it as rote learning (Williams & Cavallo, 1994). Meaningful learning is defined as "the formation of viable relationships among ideas, concepts, and information" (Williams & Cavallo, 1995, p. 626), while rote learning is defined as "memorization of content without forming relationships or making sense of the information" (Marek & Cavallo, 1997, p. 97).

Unfortunately, many students seem to learn concepts by rote rather than by meaningful learning. Rote learning is also thought to prevent the learning of new science ideas while simultaneously interfering with students' formulations of sound scientific understandings (Novak, 1988). When students consistently learn concepts by rote, they may also tend to formulate misconceptions of basic science concepts (Boujaoude, 1992).

On the same theme, educators have sought for years to foster students' conceptual understanding of physical science. Typically, learning physics concepts requires students to form understandings of central concepts and to connect new information with existing knowledge. Since many college physics courses consist primarily of lecture sessions, how can students best construct an understanding of these abstract concepts? One technique is the use of computer-aided instruction to supplement the learning which takes place in typical college physics courses. Computer-aided instruction is said to present knowledge to students in such a way as to stimulate their understanding (Flick, 1990; Faryniarz, 1992; Fredenbery, 1993; Alexander, 1993). This study investigates relationships among reasoning ability, meaningful learning, and computer-based instruction on students' understanding of Newtonian laws.

Problem Statement

The purpose of this study was to more clearly comprehend the nature and extent of students' understandings and misunderstandings of Newtonian physics. In doing so, this study investigated possible differential effects of three instructional treatments. These treatments consisted of (1) computer text instruction (consisting only of formal texts- CTI), (2) computer text-graphics instruction (consisting of three parts: texts, pictures related to the text, and audio- CTGI), and (3) computer based-instruction (consisting of four parts: texts, pictures related to the text, animation, and audio- CBI). These treatments exposed areas of students' misunderstandings of physics concept as measured by the Force Concept Inventory (FCI), an instrument developed by Hestenes et at., (1992) to determine students' misunderstandings of Newtonian physics concepts.

Specifically, the purposes of this study were:

1. To determine differences in the understanding of Newtonian physics by students exposed to one of the three different computer-aided instructional treatments (CTI, CTGI, and CBI).
2. To determine and investigate the differences among reasoning ability, treatment (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws.
3. To determine and investigate the differences among meaningful learning, treatment (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws.

Significance of the Study

An extensive literature search yielded no studies that examined all the treatments (i.e., CTI, CTGI, and CBI) simultaneously, much less the interaction between the cognitive variables (i.e., reasoning ability, meaningful learning) relative to students' understanding of Newtonian physics. When concepts were presented in a computerized visual animated format, better outcomes of instruction were achieved (Rieber, 1990). Presenting concepts as visual images or computerized visual animation may also helped physics students develop better understanding of Newtonian physics concepts. One possible reason why the computerized visual animation helped science students is that physics subject matter consists of many abstract concepts which animation makes more accessible (Escalada, Rebello, & Zollman, 1996).

This study investigated two potential benefits. The first possible benefit is increased understanding by students of the physics laws modeled in the computerized visual animations. The second possible benefit is the enhancement of the cognitive powers of students during problem solving, interpreting physics concepts, and learning activities. These outcomes might inspire students' interest in physics topics as well as their daily applications.

CHAPTER II

Introduction

Current literature review

This chapter summarizes research efforts in both evaluating and applying computers in the classroom. First, this chapter discusses the overall effects of interactive learning strategies on students' understanding through the use of computers. Second, this chapter discusses both (a) reasoning ability and (b) meaningful learning, as each relates to students' understanding of physical science concepts.

Computers and Understanding

For several years, teachers have used computer-based instruction to help improve their students' understanding of difficult concepts in education. This section reviews some recent research regarding the use of computer interactive strategies.

Knupfer and Zollman (1994) studied the use of Digital Video Interactive (DVI) techniques. DVI provides real-time motion; students can collect and visualize data as well as interact with the image on the screen. The full motion image is contained in a window on part of the screen so the remainder of the screen can be used for other purposes (i.e., graphing data). Knupfer and Zollman (1994) applied their DVI techniques to help students better learn the modern concepts of physics that have traditionally been difficult to teach, such as "frame of reference." The main objective of the DVI approach consisted of making physics concepts more visual in nature, and therefore less abstract, so that students would become more motivated to learn. The special feature of the DVI system is that it can capture video in real time and then manipulate the data obtained (Knupfer & Zollman ,1994). This feature in the Knupfer and Zollman (1994) study, referred to as Real-Time Video (RTV) by the Intel corporation, allows individual users to capture video and save it to a hard disk at 30 frames per second. It can, for example, be used to analyze the motion of a spherical pendulum which can undergo chaotic motion. To achieve this, a video camera is mounted so that it can view the end of the pendulum as it move. Then the video signal of the pendulum's image is captured by the computer. Upon completion of the video capture, an image analysis program can find the location of the end of the pendulum and recorded its coordinates for each frame of the video. With this information at hand, the motion video segment can be played back while simultaneously displaying a graph of its coordinate points. Meanwhile, other students can both graph and view the distance, velocity, and/or acceleration with respect to the time reference on the displayed video. In creating these graphs, the students in the Knupfer and Zollman study come to display a positive attitude toward the experience, with most of them claiming that the DVI visualization experience helped them to understand, for example, the frame of reference concept in physics (Knupfer & Zollman, 1994).

Guzdial (1994) examined three different treatments of computer-based instruction in relation to students' physics understanding. These three treatments were: (1) the use of simulation alone (using an expert developed model), (2) modeling alone (without a supporting simulation), and (3) computer-based modeling and simulation (a programming environment running on the Apple, Macintosh in which students construct kinematics simulations and multimedia demonstrations). Guzdial found that simulation may be used apart from modeling, by using models created by an expert. The advantage to this approach involves the avoidance of the complex activity of modeling for the students. The danger of this approach, however, is that students may not reflect on the underlying model's relevance (and its applicability as a theory) to the real world.

Guzdial (1994) also found that using modeling without computer-based simulation encourages reflection on the model and its role as a scientific theory. Unfortunately, this method may lose the potential advantages to the individual in terms of interactive exploration of the model through a simulation, which scientists typically use to gain insight into theories. Finally, Guzdial (1994) found that an approach using computer-based modeling and simulation allows students to create their own models, but only in a programming environment that offers extensive scaffolding. In the end, all three methods were evaluated on their scientific learning value. This evaluation involved a clinical interview where students were asked to solve problems verbally in physics both at the beginning and end of the classroom. Overall, Guzdial (1994) found that almost all students using computer-based modeling with simulation improved their conceptualizations of velocity, acceleration, and projectile motion better than students exposed to the other two treatments.

More recently, Escalada and Zollman (1997) compared the effect of computer simulations using interactive digital video techniques and a hands-on experiences with the concept of "reference frames." The term reference frames can be described as a set of coordinate axes attached to or moving with some specified body or bodies.

The Escalada and Zollman (1997) investigation found that the majority of participants in an introductory college physics course felt the activities (i.e., interactive digital video simulation on the computer) were either effective or very effective in helping students to learn the physics concepts related to "frames of reference". Meanwhile, students in a control group were given hands-on activities (i.e., materials, equipment, drill, and practice) to record and analyze their own data as well as formed their understanding of the concept and skill with laboratory apparatus.

Escalada and Zollman (1997) found that significant differences existed in activity-related questions (i.e., multiple choice questions developed to assess students understanding of reference frames) between the participant and control students, although no significant differences was found in final exam scores. Escalada and Zollman (1997) stated that the interactive digital video activities illustrate how technology and scientific inquiry can be integrated into a learning environment where students are given effective methods to visualize, explore, investigate, analyze, and understand physics concepts. The results of their study demonstrate that interactive digital video techniques are appropriate for the physics students and interactive digital video programs have the potential to provide physics teachers with effective exploration and application activities that incorporate existing resources and the latest user-friendly technology to bring the active process of learning physics to the classroom.

Dechsri, Jones, and Heikkinen (1997) studied the effect of laboratory manual design. Although this study is not directly related to computer-based instruction, it may be helpful to examine their results, since it relates to the cognitive as well as visual information processes of the students' learning abilities. Specifically, this design incorporated visual information-processing aids on university student learning and attitudes in a general chemistry course. In their investigation, two versions of a laboratory manual were developed: (1) an experimental version that promotes visual information processing by integrating pictures and/or diagrams with text, and (2) a control version identical to the experimental version in both activities and structure, but without pictures or diagrams.

In the study, Dechsri, Jones, and Heikkinen (1997) used three assessment instruments: (1) an achievement test to assess cognitive outcomes, (2) an attitude survey to assess affective outcomes, and (3) a manipulative skills observation checklist to assess psychomotor outcomes. Altogether, their findings indicated that the manual incorporation of visual information processing helped students gain significantly higher scores on measures of achievement and psychomotor skills, and also stimulated students to develop more favorable attitudes toward the laboratory activities.

Williamson and Abraham (1995) investigated the effect of computer animation on students' visualization of chemistry concepts. For this investigation, the Particulate Nature of Matter Evaluation Test (PNMET) was developed and used to determine both the nature of the students' visualizations of particulate matter, as well as their comprehension of the chemical concepts studied. These animations were then implemented in two treatment situations: (a) as a supplement in large-group lectures, and (b) as both the lecture supplement and an assigned individual activity in a computer laboratory.

Williamson & Abraham (1995) then compared the above two experimental treatments to a control group. Their results indicated that both treatment groups had significantly higher conceptual understanding scores on the PNMET than did the control group. Furthermore, students who viewed the animations had fewer misconceptions of chemistry concepts. This finding suggests that computer-aided instruction can be effective in mastering certain kinds of conceptual understandings

Wise (1989) conducted a meta-analysis comparing computer-based instruction with traditional instructional approaches. This analysis synthesized 26 studies (with 51 effect sizes and 4,200 students) from the second grade to the college level. From this, Wise (1989) found that student achievement was positively affected by computer-based instruction. He then divided computer usage into five categories: laboratories, tutorials, testing, simulations, and videodisc lessons. Wise (1989) found the highest effect size (ES) was with computer-based laboratories (ES = 0.76), a finding significantly higher ($p < .10$)

than that of simulation and testing usage, but not different from tutorial or videodisc usage.

Furthermore, Wise (1989) found that the effect size was greater for the physical sciences, although not significantly different from that for biological sciences (ES = 0.45 and 0.22, respectively). When looking at the grade level of computer usage, Wise (1998) found no significant differences among grade levels, although grades 9-12 and 5-8 had the highest effect size (ES = 0.40 and 0.39, respectively). Finally, there was no significant variation in effect size due to duration of treatment, method of subject assignment, source of the software, number of pieces of software, or instructional role of the software. Although not significant, he did find higher effect sizes for: (a) random assignment of subjects, (b) treatment duration of one week or less, (c) externally developed software, (d) one piece of software used, and (e) software that supplements other instructional strategies as opposed to replacing them.

Smith, Snir, and Grosslight (1987) used computer modeling with sixth and seventh grade students in an instructional unit on weight, density, and thermal expansion. The students were shown static models in which volume was illustrated by a two-dimensional square, weight by the number of dots, and density by the number of dots in each "size unit." In addition to the computer modeling, conceptual change strategies, experimentation, and demonstrations were also used. In their entirety, Smith, Snir, and Grosslight's (1987) results indicated some support for the idea that students can internalize supplied images. Finally, they found evidence that students who could successfully apply density formulas nevertheless could have no conceptual understanding of density.

A study conducted by Rigney and Lutz (1976) compared the effect of graphic and verbal presentations on 40 undergraduate students' mastery of electrochemistry concepts. Here, Rigney and Lutz (1976) found that animated graphic presentations (video tapes) helped improve the learning of complex concepts. In addition, they also found that animated graphics were superior to verbal-only presentations. They discovered that students in the animated graphic group had a better attitude toward chemistry than those students in the verbal-only group.

Working with younger students, Rieber (1990) studied the effect of computer animated and static visual aids with fourth and fifth grade learners of Newton's laws of motion. The results indicated that students exposed to the animated visuals achieved significantly higher test scores than students who were exposed to the static visuals. On the other hand, when the same experiment was conducted by Rieber, Boyce, and Assad (1990) with university students, no difference was found between the animated groups and the static groups. The authors suggested that the negative result might be due to the complication of the visual animation format itself. Another possible reason for this can be that their animation format may not have matched the developmental level of the college students.

Hays (1994) examined the effect of using three types of text- related, computer-aided instruction on students' learning outcomes. Specifically, these three types of instruction included text-only, text and static graphics, and text with animation instruction. The subjects of the study were 116 sixth, seventh, and eighth grade students. For this study, Hays (1994) dealt with the concept of diffusion. He found that the mean score on the achievement test for the text-only group was higher than the mean score for static text and text with animation groups. Hays (1994) stated two possible reasons for this unexpected result: (a) the subjects were familiar with the concept of diffusion before the study was administrated and (b) the animation was poorly designed.

Park and Gittelman (1992) carried out a study to test the hypothesis that animated visuals are better than static visuals in enhancing the learning abilities of the learner. Their findings indicated that animated visual displays in computer-based instruction were more effective than static visual displays for teaching electronic circuit troubleshooting skills. The authors believed that the selective application of animation helped the students form useful mental models of the structure, functions, and troubleshooting procedures of electronic circuits, resulting in superior performance. Park and Gittelman indicated that the implications of their study were limited to teaching novice-level skills to students with no prior knowledge of the domain.

Roblyer, Castine, and King (1988) detected seven trends in students who used computer-based instruction. There were five significant findings that relate well to this study. First, students require less time to complete a course of study. The interactive nature of computer-based instruction (CBI) allows the student to control the rate of learning, which usually results in less time on task. Second, students seem to enjoy using the computer more than sitting in the classroom receiving the same material. The students' attitudes toward the subject matter displayed in computer-based instruction do not change appreciably. However, the fact that the subject was taught using a computer did make a difference in their attitude. Third, Roblyer, Castine, and King observed that post-secondary level students responded well to CBI tutorials rather than drills. This was not true of students from the elementary level. They preferred CBI drills. Fourth, the researchers assessed that CBI more effective if it supplemented rather than supplanted instruction. And fifth, students using CBI to supplement their study of science achieve a higher level than those who do not use CBI. However, the use of CBI in other disciplines does not achieve the same positive results.

In summary, computer usage generally exerts a positive effect on student attitudes, although the effect on achievement itself varied according to the study. On this note, Koballa, Crawley, and Shrigley (1990) reported that problems regarding classroom inflexibility, lack of software, lack of computers, and limited teacher education in the use of computers all contributed to the difficulty involved with integrating computers into the classroom.

It is important to realize that there are some studies which have indicated that computer assisted instruction (CAI) has a negative effect on learning. Summerlin & Gardner (1973) compared the lecture discussion group performance with a CAI group to teach students how to balance chemical equations. A total of 110 high school students participated in the study, with 58 students in the treatment (CAI) group and 52 students in the control group. All the students in the control group were taught the same material contained in the CAI program. Their results showed that students learned more with regular classroom instruction in chemistry than they did with tutorial-type computer assisted instruction. The authors also stated that retention of the learned material was greater when learning occurred in the classroom rather than at the computer terminal. Summerlin & Gardner (1973) indicated two other critical points. First, the CAI students learned the chemistry material faster than the students in the classroom. Second, the design of the CAI materials in their study was of the tutorial type rather than the drill-and-practice or animation type, and third the lesson were of relatively short duration.

Wainright (1989) conducted a study which compared a worksheets exercise group with a CAI group in general chemistry classes in a high school. A total of 100 high school students were involved in the study, with 48 students in the treatment (CAI) group and 52 students in the control group. The treatment group used specific microcomputer software (used for the computer activity in general chemistry, distributed by COMPress, Inc.), while the control group used traditional worksheets (containing exercises) for daily reinforcement activities. The teachers presented concepts and assigned text reading identically for both treatment and control groups. The differences were only in the method of skill reinforcement in the selected concepts, whether by computer, or by paper-and-pencil worksheets. The author found in this study that the control group students' scores were significantly higher than the CAI group on the achievement. Wainright (1989) also found that the use of microcomputer materials by the experimental group did not contribute to more effective learning of concepts. The author suggested that the lack of learning the concept effectively by the computer was due to the "excessive information" in the computer software rather than the "inherent superiority" of worksheets over the CAI method.

The learning process can be investigated in many ways. One way is to study the kind of tools people have discovered and fine- tuned over the years. For example, levers, simple mechanics, and the pulley system have changed people's lives for years. Pea (1995) refers to these tools as cognitive technologies. Others like Kommers, Jonassen, and Mayes (1992) call them cognitive tools. These cognitive tools encompass technologies that enhance the cognitive powers of human beings during thinking, problem solving, and learning. Likewise, written programming languages, mathematical equations, and computer-based instruction are types of cognitive tools.

As computer-based instruction operates as a cognitive tool, the learners themselves function as designers using technologies as tools for analyzing animated events and organizing their personal knowledge. Thus, cognitive tools can help us as learners organize, restructure, and represent what we know. Representing knowledge as a meaningful task can be empowered by cognitive tools, such as multimedia authoring software (Jonassen, D.H., 1996).

One of the principles stated above for the performance of cognitive tools is the use of multimedia. Multimedia is the integration of media such as text, graphics, sound, video, and animation (Von Wodtke, M., 1993). Multimedia can stimulate more than one sense at a time, and it may possibly acquire and hold the attention of more learners.

Such cognitive tools require learners to think in meaningful ways in order to use an application's capabilities and features to represent what they know. Learners cannot learn profoundly without having access to cognitive tools that assist them in constructing and representing knowledge. Therefore, the actual power of computer-based instruction to improve education will be achieved when learners actively use them as cognitive tools instead of perceiving them as tutors or sets of facts and information. Moreover, cognitive tools are mindless tools that rely on the learner, not on computer-based instruction itself, to provide cognition. This means that thinking about an image of two or more events in a series of actions (animation) are the responsibility of the learner, not of computer technologies.

Very little research has been done to investigate the premise that cognitive tools have beneficial effects on the development of higher-order thinking skills.

Reasoning Ability

In addition to instructional procedures, other factors related to student abilities and learning approaches may explain the difficulty students have with understanding physics. One such factor is students' reasoning ability.

Research suggests that a student's ability to reason corresponds to a student's ability to understand concepts presented in the subject area of physics (Williams & Cavallo, 1995). This may result from the formal nature of concepts in physics that force students to use higher order reasoning abilities to build logical understanding. This section overviews relevant research regarding reasoning ability and concept understanding.

Piaget (1964) defined four developmental stages which students undergo in their mental development. Piaget's developmental stages are sensory-motor, pre-operational, concrete operation, and formal operation. The first two stages apply to young children. Therefore, the later two stages of development describe the types of mental operation which students who take physics courses can utilize. During the stage of concrete operations (concrete reasoning) a student's reasoning processes become logical. Patterns for logical operations such as serial ordering, conservation, classification, and improved concepts of causality, space, time, and speed emerge. On the other hand, during the stage of formal operation (formal reasoning) a student's reasoning and logic to solve all classes of problems are developed.

Bitter (1991) found that the five formal reasoning modes; proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning, account for 62% of the variance in the scientific achievement test scores of students. Literature shows that many college students are not formal operational reasoners (Renner, Stafford, Lawson, McKinnon, Friot, & Kellogg, 1976). However, college students are required to learn formal concepts, especially in physics. Many college students who have difficulty understanding physics concepts often have misconceptions. Hestenes, Wells, and Swackhamer (1992) define the word, misconception, as an understanding that differs from the understanding believed by experts in the field. It is likely that these misconceptions may be due to the abstract content in physics. When concrete operational students try to learn formal physics concepts, a conflict takes place between the learner's reasoning ability and a desire to understand the physics concept. As a result, understanding formal concepts may be troublesome for learners who have not developed formal reasoning abilities.

Williams and Cavallo (1995) examined relationships among students' reasoning ability, meaningful learning approaches, and their understanding of Newtonian physics. Their research indicates that reasoning ability and meaningful learning are correlated to students' understanding of physics concepts. Moreover, students who have low reasoning ability or learn by rote memorization develop more misconceptions and poorer understandings of physics concepts. Those students who had high reasoning ability and used more meaningful learning strategies had greater understanding of physics with fewer misconceptions.

Other researchers have also found that there is a link between reasoning ability and concept understanding. Renner and Marek (1988) contrasted concrete concepts (those that can be directly experienced) with formal concepts (those that require formal reasoning ability). Other researchers have also found that formal reasoning ability is necessary to understand formal concepts (Lawson & Renner, 1975; Simpson & Marek, 1988).

Simpson and Marek (1988) investigated the understandings and misconceptions of biology concepts among students in both small and large high schools. Students' concept understandings and misconceptions were measured with concept evaluation statements (CESs). These statements described situations and asked students to use biological concepts in answering questions about each given situation. Each concept evaluation statement described one of four biological concepts: diffusion, homeostasis, classification of animals and plants, or food production in plants. The authors indicate that using concrete instruction (i.e., those that can be understood only through direct experiences with objects, events or situations which generate data from which the concepts can be formed) to teach science courses may decrease the instances of concept misunderstandings that students hold. Simpson and Marek (1988) also argue that concepts taught should be matched to the developmental level of the learner.

Brown and Clement (1989) investigated the use of examples when attempting to remediate conceptual misunderstandings of physics concept among students. In this study, the author questioned the effectiveness of traditional teaching by the example technique. Furthermore, the establishment of analogical connections and the ordering of examples can be important and helpful to learning. According to Brown and Clement (1989), teachers need to be aware that examples which they find compelling may not be illuminating for their students. Even when an example is fascinating to a student, it may not be seen as analogous to target problems, and it may result in misconceptions. He suggests that further research is needed to provide more conclusive answers to remediate misconceptions in physics among students. Though not considered by Brown, one of the ways to remediate misunderstandings in physics studies among students might be the use of computer-based instruction. For example, graphical animation has been used effectively to teach highly abstract and dynamic concepts in physics, such as Newton's Law (diSessa, 1982), because the visualization of the object's movement is critical to understanding the concept (White & Frederiksen, 1990). Also, the direct observation of the concept (e.g., velocity of a projectile) in the movement of an actual object is not readily apparent.

Clement (1987) studied the use of analogical reasoning to help students overcome misconceptions regarding Newtonian physics. Clement (1987) utilized three different approaches to increased student comprehension: (1) questions posed to the students encouraging them to become actively involved in learning; (2) using key examples to activate useful intuitions possessed by students; and (3) using analogical reasoning that has been observed in the solutions of experts' problem solving methods. The author concluded that students made some progress in changing their mind about Newton's third law (i.e., for every action there is an equal, but opposite, reaction) at an acceptable conceptual level. However, he discovered that despite his three approaches, misconceptions about Newtonian laws of physics persisted. It would be very interesting to examine the possible use of computer-based instruction using animated sequences as a tool to help students overcome certain difficulties in understanding Newtonian physics concepts. Animation in visual displays has three primary instructional roles: as a device for attracting attention and maintaining motivation (Rieber, 1991); as a means for representing domain knowledge involving explicit or implicit movement (e.g., simulation; diSessa, 1982; White, 1984); and as an aid for explaining complex knowledge or phenomena (e.g., structural or functional relationships among components; Woolf, Blegan, Jansen, & Verloop, 1986).

There is some evidence that reasoning ability can influence conceptual understanding. Renner (1985) and Lawson & Renner (1975) have also illustrated the usefulness of matching concept to the developmental level of the learner. However, some researchers have argued that learning occurs as a result of interaction between new and existing conceptions Hewson and Hewson (1984). These results indicate a need for further investigation into the leading causes of misconceptions and the instructional approaches needed to remediate misconception among students. Furthermore, since reasoning ability is related to better understanding of physics concepts, there is a need to investigate the effects of computer-based instruction with students who have lower reasoning abilities.

Meaningful Learning

Another factor related to physics understanding is students approaches to learning as either meaningful or rote (Williams & Cavallo, 1994).

Recent research in science education reveals that many students do not construct in-depth understandings of concepts of science. Instead, most students seem to learn concepts by rote approaches rather than by meaningful learning approaches (Williams & Cavallo, 1995).

Previous studies that compared diverse patterns of students' meaningful and rote approaches to learning have found clear differences in the understandings they gained (Atkin, 1977; Cavallo, 1991; Cavallo & Schafer, 1994; Donn, 1989; Edmonson, 1989; Robertson, 1984). This section reviews some recent research regarding both meaningful (or rote) learning and concept understanding.

Ramsden and Entwistle (1981) investigated several factors concerning approaches to studying. These included: (a) developing personal meaning (based on intrinsic motivation), (b) reproducing (a surface approach based on fear of failure), and (c) achieving (based on career motivation, or a hope for success). Ramsden and Entwistle (1981) found that developing a meaningful learning orientation related positively to achievement. The extent to which students use meaningful or rote approaches to learning new ideas is called their "learning orientation." Moreover, such other factors as good teaching methods, freedom in learning, and not over-burdening the students represent good teaching practices that tend to promote deeper more personal learning orientations. Ramsden and Entwistle (1981) conclude that these factors should also promote the quality of what is learned.

Entwistle and Waterston (1988) examined students' styles of studying. They hypothesized that "approaches to studying are a product of the interaction between characteristics of individual students and their perceptions of the courses, teaching, and assessment procedures" (Entwistle & Waterston, 1988, p. 264). Moreover, the authors found that students who took a surface approach (fear of failure) to learning, retained less factual material than those who took a deeper approach (evaluates and compares) to learning. This finding supports the notion that those students who learn concepts meaningfully will understand those concepts better than the rote learner.

Boujaoude (1992) investigated the differences between rote and meaningful learners in understanding chemistry concepts. Boujaoude (1992) examined high school students who were taught in both lecture and laboratory. From this investigation, he found that meaningful learners performed significantly better than rote learners on a chemistry misunderstanding test. Furthermore, Boujaoude (1992) found that meaningful learners appear better able to relate information acquired in the classroom to their prior knowledge and store the information in bigger, more organized chunks. From these findings, the author reasoned that it is essential to teach students how to be meaningful learners.

The question here is what instructional strategies can be effective with rote learners. The cognitive variables (i.e., meaningful learning, rote learning) may be influenced by instructional treatments like these in this study (CTI, CTGI, and CBI). If these treatments cause students to learn with more understanding of concepts then they would be of great value to the learners.

Cavallo and Schafer (1994) explored various factors predicting the extent to which high school students acquired understandings of three basic biological topics. These three topics were: (1) meiosis, (2) the Punnett square method, and

(3) the relationships between both topics. Their findings indicated that meaningful learning orientation contributes to students' attainment of understanding in a manner independent of ability and achievement motivation. Cavallo and Schafer (1994) determined that student's tendencies to learn meaningfully or by rote predicted their attainment of meaningful understanding of these biology concepts. Furthermore, a direct relation also exists between meaningful learning orientation and students' understanding. Cavallo and Schafer (1994) conclude that science learning may not be restricted by a student's particular ability, and may instead be related to how they approach learning (meaningful or rote).

In the same year, Cavallo (1994) suggested that educators need to help students view science as a continuous process of exploration. Accordingly, teachers need to assist students in building understandings of the world around them, instead of simply emphasizing the memorization of textbook definitions and facts.

In a subsequent study, Cavallo (1996) investigated the relationships between four different learning techniques regarding genetics topics. The techniques included: (1) students' meaningful learning orientation (meaningful or rote), (2) reasoning ability (pre-formal or formal) and acquisition of understandings of genetics topics, (3) ability to solve genetics problems, and (4) the interaction of these variables on students' performance on the different tests. Findings indicated that students who approach learning with the attempt to make connections among ideas, facts, and information or meaningful learning have a greater understanding of the topics of meiosis. Cavallo (1996) also found that such students had a greater understanding of the relationships between meiosis and Punnett square diagrams and were able to solve genetics problems more effectively.

Students who have a more meaningful learning approach do not necessarily have high reasoning ability. Cavallo (1996) concluded that both meaningful learning orientation and reasoning ability help students better understanding the meaning of the symbols in the use of Punnett square diagrams and how to use the diagrams to solve genetics problems.

A study conducted by Dickie (1994) investigated the meaningful learning orientation of college physics students in Canada. Dickie (1994) found that most students learned physics by memorizing formulas rather than understanding the concepts involved. The author concluded that a large segment of the students in college learned physics by rote. In addition, students who applied the meaningful learning approach scored significantly higher on the Force Concept Inventory (i.e., an instrument that was developed by Hestenes et at., (1992) to determine students' misunderstandings of Newtonian physics concepts) than those with a rote learning approach. Finally, Dickie (1994) suggested that other educators need to adopt strategies that encourage meaningful learning.

In summary, the meaningful learning approach indicates that learners must have the tendency to make connections between science concepts. The literature, however, suggests that this tendency to formulate relationships remains important in spite of how learners acquire new concepts (Osborne &

Wittrock 1983, 1985). Moreover, such research also reveals additional information as to how students learn new concepts in science. In addition, some studies indicate a direct relationship between meaningful learning and students' understandings of concepts. Altogether, these findings suggest that the more meaningful a student's learning orientation, the more meaningful the understandings the student will tend to accomplish the task at hand.

The concepts learned by a rote learner may not make sense, and also do not tend to become relevant to the learner. As a result, the rote learner can quickly forget important concepts.

Many studies have been done with regard to computer-based instruction, reasoning abilities, and meaningful learning. None, however, have examined all of these factors simultaneously, much less the interaction between these variables relative to students' understanding of Newtonian physics.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

An experimental study was conducted using three groups (CTI, CTGI, and CBI). The control group received textual information in the CTI format. The two experimental groups received treatments in either the CTGI or CBI format, but not both. A posttest instrument, the Force Concept Inventory (FCI), was used to assess each group.

Campbell and Stanley (1963) suggested that for one to protect against threats to external validity—such as wide variations in pre-study knowledge on a given subject—the researcher should devise a means to determine sample characteristics before getting underway. A pretest might threaten external validity, but an instrument aimed at eliminating outliers and creating a more homogeneous group might achieve greater validity.

Each student in the sample was subjected to a battery of questions taken from validated instruments used to assess physics knowledge (see Appendix B). Twenty questions were used to assess the students' familiarity with physics concepts. Those scoring 17 or higher were eliminated from the study and those scoring 16 or below were retained. The group scoring 16 or below provided a homogeneous, physics knowledge characteristic vital to this experiment.

The treatment consisted of three separate groups: (1) computer text instruction (CTI), (2) computer text-graphic instruction (CTGI), and (3) computer based-instruction (CBI). The first, computer text instruction, consists only of texts. The second, computer text-graph instruction, contains three parts: texts, pictures related to the text, and audio. The third, computer-based instruction, contains four parts: texts, pictures related to the text, animation, and audio.

As mentioned above, only the CBI section of treatment contains an animation part. The animation part has seven different animation segments: (1) a projectile motion (an object that is projected by some force and then follows a path determined by the gravitational force acting on it and by air resistance), (2) an airplane moving while dropping a cargo, (3) Newton's third law (for every action there is an equal, but opposite, reaction), (4) two balls colliding with each other, (5) Galileo's experiment of inclined planes, (6) two different objects dropped on the Moon's surface, and (7) a car moving while showing its net forces.

All three groups (CTI, CTGI, and CBI) received instruction in a common lecture section conducted by the course professor. The subject matter of this instruction was Newton's laws. This subject matter was selected because: (a) most of the students enrolled in the first-semester "Physics for Life Science" course did not have prior knowledge of Newton's laws; (b) Newton's laws normally occupy a significant portion of most first-semester "Physics for Life Science " courses; and (c) Newton's laws typically form a significant portion of class during the second and third weeks of a sixteen-week semester, allowing a window of opportunity for the administration of posttests.

Sampling Procedures

The samples for this study consisted of students enrolled in the fall semester of the "Physics for Life Science" course at a comprehensive university. To obtain accurate information, encourage collaboration, and increase the number of student volunteers, students were informed that their identity would be confidential. Overall, this course had five discussion sections ranging from 35 to 40 students with a total enrollment of 180 students. Of the 180 students, 90 students fully participated in this study.

The sample consisted of 41(45.6%) men and 49 (54.4%) women. Of the 90 students in the sample, there were 59 (65.6%) Caucasian/White, 11 (12.2%) Asian-American, 4 (4.4%) African-American, 3 (3.3%) Hispanic/Latino, 7 (7.8%) Native American and 6 (6.7%) other (see Figure 1). The ages of the students ranged from 18 to 34 years old (see Figure 2). All students were non-physics majors enrolled in pre-professional science programs (e.g., Biology, Environment) requiring the "Physics for Life Science" course.

There were three class lectures of 50 minutes per week. Newton's laws were taught in class from the second through the fourth week of the semester within the time frame of the experiment. The course instructor had taught for more than five years. This instructor has received favorable teaching evaluations from students in past semesters, holds a doctoral degree in physics, and is interested in the quality of undergraduate courses. Throughout this experiment, one teaching assistant taught one discussion section and another teaching assistant taught the remaining four sections.

The discussion period consisted of a twenty-five minute problem-solving period followed by the experimental treatment. One hundred eighty students were randomly assigned to one of the three treatment groups (CTI, CTGI, or CBI) and exposed to twenty-five minutes of the treatment in the fourth week of the semester in the computer lab. During the treatment, students interacted with the critical points of Newton's laws on the computer screen. Students were not allowed to repeat the treatments. The content (e.g., text, picture, animation, and audio) of each treatment (CTI, CTGI, and CBI) was programmed by the researcher using the Authorware Programming Language version 3.0. The computer lab work was supervised by the researcher.

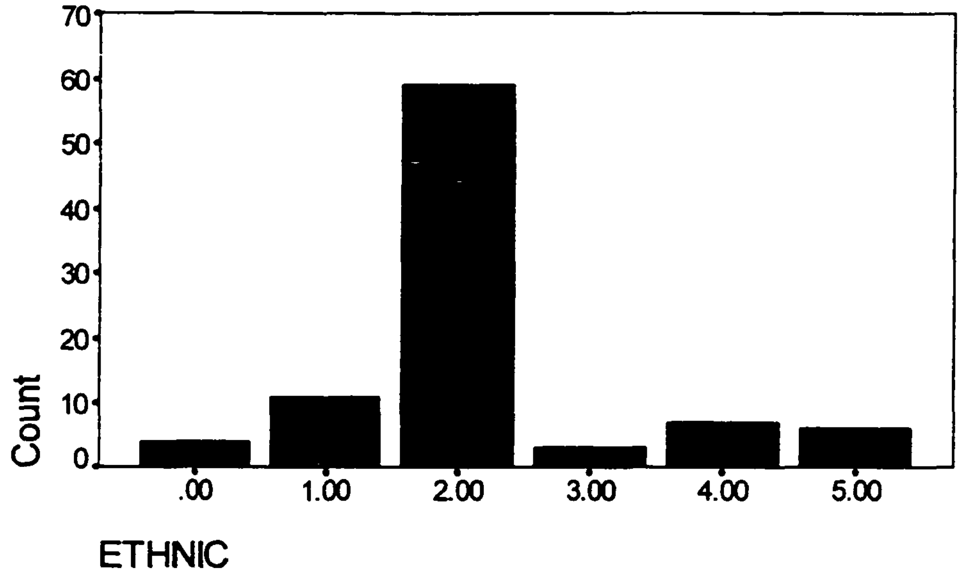
Students who missed the computer lab could not make up this assignment. Furthermore, to ensure unbiased sampling, only those subjects who missed no more than one lecture (and who attended the computer lab assignment as well) were included as subjects in this study.

Aside from the attendance consideration, the subjects were informed that they would be quizzed over the material at the end of the computer lab. All students used the computer lab on an individual basis, and they had no interaction with other students.

Statistical Analysis

Descriptive statistics were generated for the responses to each of the three instruments used in this study (Test of Logical Thinking, Learning Approach Questionnaire, and Force Concept Inventory).

Figure 1. Sample Structure According to Ethic Background.

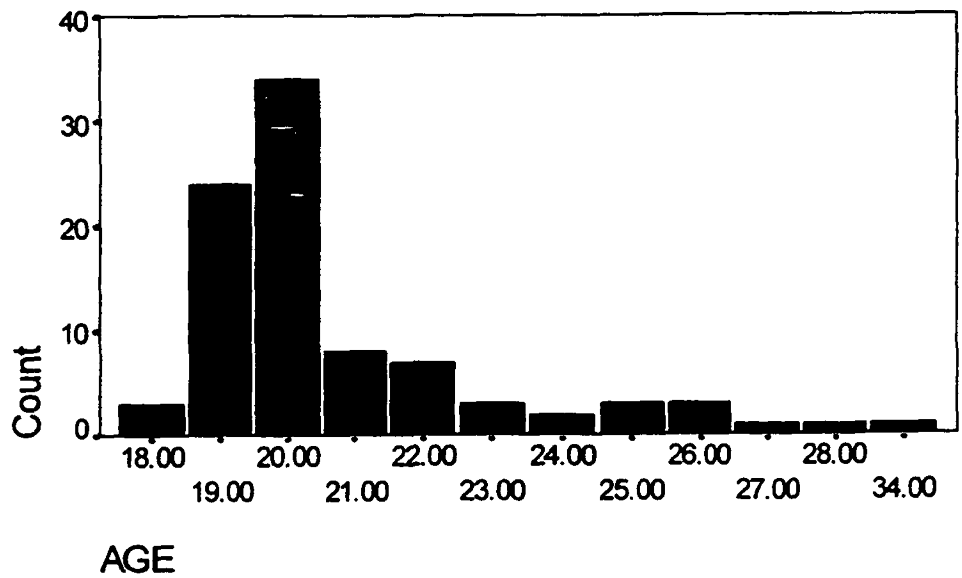


0 = African American 1 = Asian American 2 = Caucasian / Non Hispanic

3 = Hispanic American 4 = Native American 5 = Other

- 41(45.6%) men and 49 (54.4%) women.
- 59 (65.6%) Caucasian/White,
- 11 (12.2%) Asian-American,
- 4 (4.4%) African-American,
- 3 (3.3%) Hispanic/Latino,
- 7 (7.8%) Native American &
- 6 (6.7%) other.

Figure 2. Sample Structure According to Age.



A correlational analysis was used to analyze the relationship between the dependent variable (level of conceptual understanding of physics) and the independent variables (reasoning ability and meaningful learning).

To determine differences among the three treatment groups, a one-way analysis of variance (ANOVA) was performed using scores on the Test of Logical Thinking. Two-way analysis of variance was used to analyze differences among groups with reasoning ability, meaningful learning, and the interaction as independent variables. The Force Concept Inventory was the dependent variable. Thus, each of the two research questions below is followed by the measures and statistics used to answer the question:

1. What are the differences among reasoning ability, treatment methods (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws? The Force Concept Inventory (FCI) test scores were used to determine students' understanding of Newton's laws among the CTI, CTGI, and CBI groups respectively. The descriptive statistics (i.e., means and standard deviations) were calculated.

2. What differences exist among meaningful learning, treatment methods (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws? The Force Concept Inventory test scores were used to determine students' understanding of Newton's laws among CTI, CTGI, and CBI groups. The descriptive statistics (i.e., means and standard deviations) were calculated.

Instruments

Through the entirety of this research study, one dependent variable was measured: the level of conceptual understanding of Newton's laws. Two independent variables (reasoning ability and meaningful learning) were also measured. Three instruments were used to measure the aforementioned variables as described in the following sections:

Force Concept Inventory

The first instrument, the Force Concept Inventory (FCI), was developed by Hestenes, Wells, and Swackhamer (1992). The FCI is one of the most widely used instruments in physics. It was administered immediately following the treatment in the fourth week of the semester to determine students' misunderstandings of Newtonian physics concepts. The FCI consisted of 29 multiple-choice items designed to identify Newtonian physics misunderstandings. Questions 20 and 21 were omitted from the FCI as the students found the questions confusing in the pilot study (conducted by the researcher in the summer of 1998). This instrument forces students to choose between correct and incorrect responses. The higher the score on the FCI, the fewer the misunderstandings and the greater the students' understanding of Newton's laws. The Kuder-Richardson reliability for the FCI is .86 if used as the pretest, and .89 if used as the posttest (Hestenes, Wells, and Swackhamer, 1992). In addition, Hestenes, Wells, and Swackhamer (1992) have also established both the face and content validity of the items. As far as the percentage on Bloom's scale, 44.4% of the questions were at the application level, 18.5% were at the analysis level, 18.5% were at the comprehension level, 11.1% were at the synthesis level, and 7.4% were at the evaluation level. The FCI was used as a posttest of 27 questions. The researcher added one open-ended question in the posttest. An example of an open-ended question was:

A bowling ball accidentally falls out of the cargo bay of an airliner. Suppose you see this from the ground. Draw the path which the bowling ball most closely follows after leaving the airplane. A copy of the FCI used as a discrimination tool can be found in Appendix B. The FCI posttest is presented in Appendix C.

Test of Logical Thinking

The Test of Logical Thinking (TOLT) was used on the first day of class to determine each student's reasoning ability. The TOLT is a ten-question instrument measuring: (a) controlling variables, (b) proportional reasoning, (c) combinatorial reasoning, (d) probabilistic reasoning, and (e) correlational reasoning. Each item requires a response, along with a justification for the response. The scores on the TOLT range from 0 to 10, with 10 representing complete formal operations. A student is give one point for a correct answer and no point for an incorrect answer. A student scoring five points or less was labeled a concrete learner. A student scoring six points or higher was labeled a formal learner. Internal reliability is reported for students from grade 6 through college as .85 (Tobin and Capie, 1981). Moreover, the criterion validity between the TOLT and Piagetian interview is .80 (Tobin and Capie, 1981).

Learning Approach Questionnaire

The Learning Approach Questionnaire (LAQ) administered during the second week of discussion section, comprises a 50-item Likert-type instrument. This instrument measures: (1) student tendency to learn meaningfully or by rote, and (2) students' epistemological views (beliefs about the processes of knowing) of science (Boujaoude, 1992; Cavallo, 1991; Donn, 1989; Entwistle & Ramsden, 1983). This study used only those questions (20 total) that emphasize students' meaningful and rote approaches to learning. The instrument asks students to respond to questions regarding how they learn, ranging from A (always true) to E (never true).

Sample questions from the LAQ follow:

	Never True				Always True
13. While I am studying, I often think of real life situations to which the material I am learning would be useful.	A	B	C	D	E
15. I find I have to concentrate on memorizing a good deal of what I have to learn.	A	B	C	D	E

A response of "always true" on Question 13 above indicated a strong tendency toward meaningful learning, whereas a response of "always true" on Question 15 indicated a strong tendency toward rote learning.

A Cronbach alpha internal consistency coefficient for this instrument was reported as .80 (Cavallo, 1996) for a sample of 11th-grade chemistry students. A copy of the LAQ appears in Appendix D.

Computer Text Instruction

The Computer Text Instruction (CTI) lesson consisted only of formal texts. The content of the CTI lesson included Newton's laws of motion, projectile motion, and momentum. The CTI software was kept in a general physics computer lab, and students accessed the CTI lesson following the fourth week of the discussion section. The computer lab was open to students only during the treatment. See Figure 3 for a sample screen of the CTI lesson and a complete copy in Appendix E.

Computer Text-Graphic Instruction

The Computer Text-Graphic Instruction (CTGI) lesson contained three parts: text, static pictures related to the text, and audio. The content of the CTGI lesson included the same content as the CTI lesson (Newton's laws of motion, projectile motion, and momentum). The CTGI lesson was also kept in a general physics computer lab, and students also accessed the CTGI lesson following the fourth week of the discussion section. The computer lab was open to students only during the treatment. See Figure 4 for a sample screen of the CTGI lesson and a complete copy in Appendix F.

Computer-Based Instruction

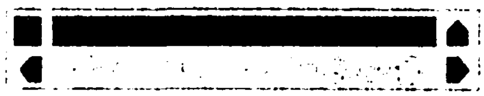
The Computer-Based Instruction (CBI) lesson contained four parts: text, static pictures related to the text, audio, and eight different animation sequences. The content of the CBI lesson included the same content as the CTI lesson (Newton's laws of motion, projectile motion, and momentum). The CBI lesson was also kept in a general physics computer lab, and students accessed the CBI lesson following the fourth week of the discussion section. The computer lab was open to students only during the treatment. See Figure 5 for a sample screen of the CBI lesson and a complete copy in Appendix G.

The CTI, CTGI, and CBI content was reviewed by an expert panel consisting of: (a) a college physics professor, (b) a high school physics teacher, (c) a science education professor, and (d) an instructional system design expert. As a result, several changes in the vocabulary of content of both Newton's law of motion as well as momentum, and animation of the CBI were made according to their recommendations. The CTI, CTGI, and CBI lessons were also pilot-tested with forty students in the summer of 1998. Of these forty students, six students from the pilot study were interviewed regarding their related interpretations and understandings of content in each treatment condition. In addition, pencil and paper were provided for students' comments regarding interpretation and understanding of content, screen graphics, and the use of animation in each treatment condition. As a result, the suggested modifications obtained from the reviews, pilot test, interviews, and pencil and paper responses were used to produce the final forms of the CTI, CTGI, and CBI lessons.

Screen # 1-30 **CTI**

Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.

CONTINUE



AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Figure 4. Computer Text-Graphic Instruction Screen

Screen # 1-50 **CTGI**

Projectile motion-
A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.	

Figure 5. Computer-Based Instruction Screen

Screen # 1-140 **CBI**

The conservation of momentum- When there is no external net force on an object, if two objects collide with each other, the momentum before collision is equal to the momentum after collision.

It means that momentum is conserved in collisions between objects.

CONTINUE

Options Glossary

AUDIO:

The conservation of momentum- When there is no external net force on an object, if two objects collide with each other, the momentum before collision is equal to the momentum after collision.

It means that momentum is conserved in collisions between objects.

PROGRAMMING INSTRUCTIONS:

CHAPTER IV

Results

Statistical analyses were performed to answer the three questions of this study. For the benefit of the reader the information in this chapter has been arranged in the following order: (1) The results of the Test of Logical Thinking (TOLT), and (2) An analysis of each of three research questions.

Eighty-two of 180 students failed to meet their obligations and were eliminated during the study. Eight additional students were eliminated because they exhibited an unusually high degree of knowledge of physics, threatening the study's external validity. The results contained within this chapter reflect data collected on the remaining 90 subjects.

The TOLT

The TOLT was administered to the students during the second week of the semester. The TOLT contains ten items, two items each that measure proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. The scores for each of the five types of reasoning range from zero to two, thus total scores for the TOLT range from zero to ten. The three treatment groups in this study have similar TOLT scores. The means for the TOLT score and for each type of reasoning are reported for the treatments groups in Table 1.

Table 1.

Descriptive Data for the TOLT

Reasoning Mode	Mean Score for Treatment		
	CTI	CTGI	CBI
Proportional Reasoning	1.6774	1.6000	1.7586
Controlling Variable	1.6129	1.5667	1.6207
Probabilistic Reasoning	1.2581	1.4000	1.3793
Correlational Reasoning	.8387	1.0333	1.1724
Combinatorial Reasoning	.3871	.2667	.4138
TOLT Score	5.7742	5.8667	6.3448
S.D.	2.4043	2.1613	2.5252

Group means for the TOLT scores ranged from 5.7742 to 6.3448. A one way analysis of variance found no significant difference in the TOLT scores of the computer text instruction (CTI), computer text-graphic instruction (CTGI), and computer-based instruction (CBI) groups. These results suggested that the groups could be considered equivalent. Appendix J gives the TOLT score and the score for each of the five types of reasoning for every subject. Table 2 contains the ANOVA results for this comparison.

Table 2.

ANOVA Results for TOLT Scores in the Treatment Groups

S of V.	Sum of sq.	D.F.	Mean sq.	F	P
Between	5.551	2	2.776	.495	.611
With	487.438	87	5.603		
Total	492.989	89			

Research Question One

The first research question dealt with conceptual understanding. It stated: To determine differences in the understanding of Newtonian physics by students exposed to one of the three different computer-aided instructional treatments (CTI, CTGI, and CBI).

Concept understanding was measured by the Force Concept Inventory (FCI). The FCI was given during the fourth week of the semester following the treatment. The scoring key for the FCI is in Appendix C. The FCI had 27 items with a maximum possible score of 27. Appendix I contains the performance of each student on the 27 items. Means for each of the treatment groups are in Table 3.

ANOVA results for the FCI are presented in Table 4. The ANOVA results reveal a significant difference in the FCI score by treatment. Differences at the .05 level were followed by Newman-Keuls post hoc tests to determine which

Table 3.

Group Means on The FCI

Treatment	Count	Mean	Std. Deviation	Std. Error	95 Pct. Con.
CTI	30	11.7333	4.1848	.7640	10.17 - 13.30
CTGI	30	13.9667	5.5428	1.0120	11.90 - 16.04
CBI	30	16.9000	4.2210	.7707	15.32 - 18.48
Total	90	14.2000	5.1039	.5380	

pairs of the three treatment groups means differed. The CBI group had scores significantly different from those of either the CTGI or the CTI groups. However, the score of the CTI and CTGI groups were not significantly different (see Figure 6).

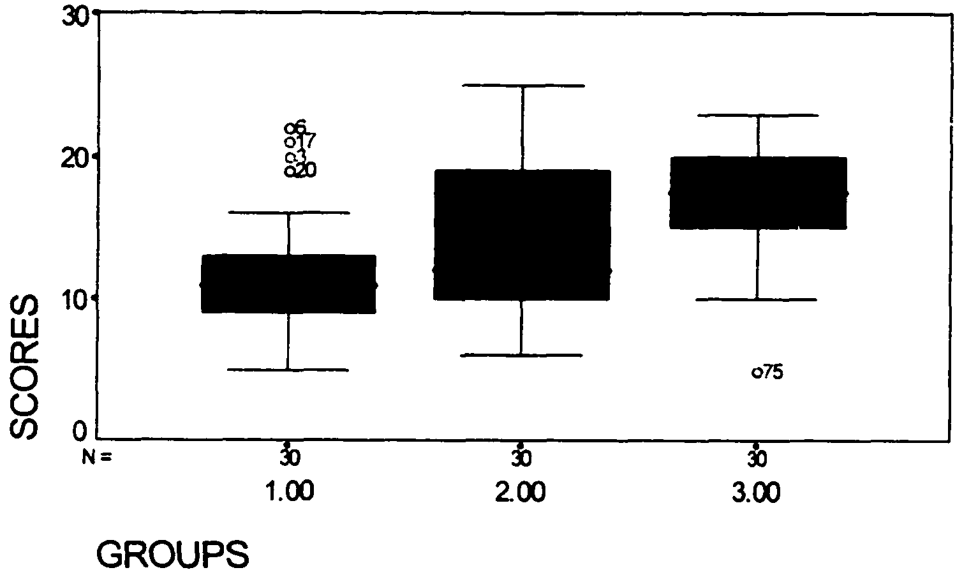
Table 4.

ANOVA Results for the FCI Scores in the Treatment Groups

Source	Sum of sq.	D.F.	Mean sq.	F	P
Between	402.8667	2	201.4333	9.1487	.002 *
Within	1915.5333	87	22.0176		
Total	2318.400	89			

* The mean difference is significant at the .05 level.

Figure 6. Boxplot of FCI Scores.



1 = CTI

2 = CTGI

3 = CBI

An interesting difference among the groups was found when the subjects were asked to draw the path a bowling ball would take if it accidentally fell out of the cargo bay of an airliner (item 21, FCI). Some students were able to depict the path taken by the falling bowling ball; others were not able to depict the ball's path. Only 52% of the CTI group drew this correctly, while 57% of the CTGI group and 88% of the CBI group drew it correctly.

The close proximity of results between the CTI group and the CTGI group, as compared to the CBI group, suggests that the physical relationship between an object's velocity and its downward path are spatially determined and may not be cognitively assessed using only a logical-mathematical frame of reference. The CTI format relied on the student's ability to visualize the event after a brief textual explanation. The CTGI format relied on a student's ability to create a three-dimensional mental model based on a two-dimensional drawing. But the CBI format, using an animation of the event, bypassed the shortcomings of those students limited by spatial perceptions and filled in the knowledge gaps.

If one were to agree with Gardner's (1993) assertion in *Frames of Mind* that intelligence can be exhibited in one of many ways, then perhaps the sample groups did not possess many individuals having spatial intelligence. This might explain why a large number of students misunderstood the concept when it was given in class during the third week of the semester and why it was missed again in the CTI and CTGI formats.

Table 5.

Post Hoc (Pairwise Comparison) Effect: TreatmentDependent : FCI

Significant level: .05

Group (I)	Group (J)	Means Difference (I - J)	Std. Error	P-Value
CTI	CTGI	-.1333	.108	.449
	CBI	-.6333 *	.108	.000
CTGI	CTI	.1333	.108	.449
	CBI	-.5000 *	.108	.000
CBI	CTI	.6333 *	.108	.000
	CTGI	.5000 *	.108	.000

* The mean difference is significant at the .05 level.

To assess the magnitude of a difference between the means of two groups is to calculate what is known as effect size (ES). The effect sizes were calculated by dividing the difference in the means of the CTI group and the CTGI or CBI group by the standard deviation of the CTI group. An effect size of .5263 was found between the CTGI group and the CBI group on the FCI. An effect size of 1.2346 was found between the CTI group and the CBI group on the FCI. The CBI treatment resulted in an increase of the mean score of about 5.1667; a standard deviation from the CTI group.

Research Question Two

The second research question dealt with student reasoning ability and the treatments. It stated: To determine and investigate the differences among reasoning ability, treatment (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws.

As show in Tables 6 through 8, no significant difference, $F=3.613$; $P=.061$ was found in student reasoning ability and the treatments as measured by scores of the FCI. Although not significant ($P=.061$), the portion of the variance explained by reasoning ability was relatively high. However, Table 6 shows that reasoning ability alone accounted for 21.5% of the observed variance for the scores of the FCI. This indicated that the chance of finding significant results was likely. Thus, although the observed variance explained by the reasoning ability was relatively high, the finding of no significance gives greater relevance to these results than the percentage (21.5%) indicates. Appendix J contains the performance of all individual students' TOLT scores on the 10 items.

Tables 7 and 8 shows no significant difference between the means of the concrete and formal learners (see Figure 7). The higher mean achieved by concrete learners (15.191) may indicate an overall better understanding of Newton's laws than formal learners (13.116). Those students who did not possess the reasoning ability needed to understand spatial concepts may have resorted to memorizing facts, formulas, and problem types to get through physics courses (Hammer, 1989; Hewett, 1995; Renner & Marek, 1988). Another

Table 6.

Univariate Analysis of Variance for the FCI Scores in the Treatment Groups VS. Concrete and Formal Reasoning Students

Source	Sum of sq.	D.F.	Mean sq.	F	P
Corrected Model	499.264*	5	99.853	4.611	.001
Intercept	17943.653	1	17943.653	828.562	.000
Groups	376.291	2	188.146	8.688	.000
Concrete/Formal	78.253	1	78.253	3.613	.061
(Groups)(Concrete)	17.671	2	8.835	.408	.666
Error	1819.136	84	21.656		
Total	20466.000	90			
Corrected Total	2318.400	89			

* R Squared = .215

Table 7.

Descriptive Statistics for the FCI Scores in the Treatment Groups VS. Concrete and Formal Reasoning Students

Groups	Concrete/Formal	Mean	Std. Deviation	N
CTI	Concrete Student	13.0000	4.8358	14
	Formal Student	10.6250	3.2838	16
	Total	11.7333	4.1848	30
CTGI	Concrete Student	14.2353	5.3564	17
	Formal Student	13.6154	5.9797	13
	Total	13.9667	5.5428	30
CBI	Concrete Student	18.1250	3.7572	16
	Formal Student	15.5000	4.4159	14
	Total	16.9000	4.2210	30
Total	Concrete Student	15.1915	5.0975	47
	Formal Student	13.1163	4.9435	43
	Total	14.2000	5.1039	90

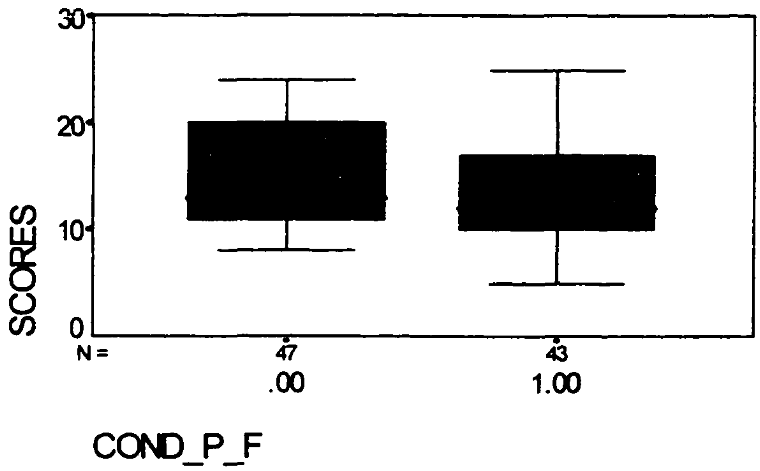
Table 8.

Groups Comparison for the Concrete and Formal Reasoning Students

Depcndent : FCI

Group (I)	Group (J)	Means Difference (I - J)	Std. Error	95 Pct. Con.
CTI	Concrete S.	13.000	1.244	10.527 - 15.473
	Formal S.	10.625	1.163	8.311 - 12.939
CTGI	Concrete S.	14.235	1.129	16.480 - 16.182
	Formal S.	13.615	1.291	11.049 - 16.182
CBI	Concrete S.	18.125	1.163	20.439 - 17.973
	Formal S.	15.500	1.244	13.027 - 17.973

Figure7. Boxplot of FCI Scores VS. Concrete & Formal Learner.



0 = Concrete Learner

1 = Formal Learner

explanation might be that the concrete learners might have resonated better with the subject matter than the formal learners. When compared with formal learners (FL) the means of the concrete learners (CL) were always higher [CTI: 10.63(FL) VS. 13.00 (CL); CTGI: 13.62 (FL) VS. 14.24 (CL); CBI: 15.5 (FL) VS. 18.13 (CL)].

It appears from Table 6 that there is no evidence of interaction ($\underline{P}$<.666) between the treatment and reasoning ability variables on students' understanding of Newton's laws.

Research Question Three

The third research question dealt with students' meaningful learning and the treatments. It stated: To determine and investigate the differences among meaningful learning, treatment (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws.

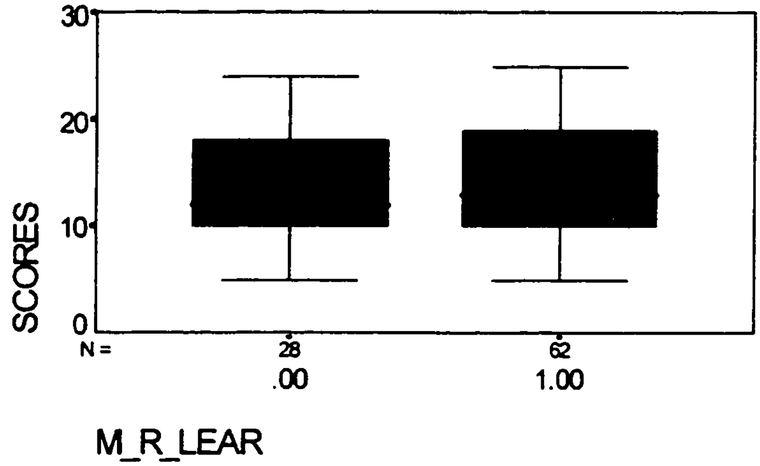
As show in Tables 9 through 11, no significant difference, $\underline{F}$=.877; $\underline{P}$=.352 was found in student's meaningful learning and the treatments as measured by scores on the FCI. However, Table 9 shows that meaningful learning alone accounted for 18.2% of the observed variance for the scores of the FCI. Regardless of the relatively high variance in percentage (18.2%) attained, the results do indicate that a meaningful learning approach contributes to a portion of the overall learning that takes place in the classroom that teachers can help develop among their students. The remainder of the variance not explained by a meaningful learning approach is likely explained by other factors such as general aptitude. In fact, Table 10 shows that the meaningful learning approach students had a higher overall mean understanding of Newton's laws. Appendix J contains the performance of each student on the LAQ's 30 items. The meaningful learning approach students mean was 14.4194, while the rote learning approach students mean was 13.7143 (see Figure 8). These results are not unusual since an understanding of physics consists of many abstract concepts.

This result indicates that students with a meaningful learning approach did not necessarily achieve greater understanding of Newton's laws as measured by scores of the FCI. This result was consistent with Cavallo's (1996) findings that there is no relationship between meaningful learning orientation (the extent to which students use meaningful or rote approaches to learning new ideas) and students' understanding of topics in genetics.

The data also indicated that meaningful learning approaches were separate constructs for this sample, as measured by the LAQ. This finding was not consistent with the results of the previous study (Cavallo & Schafer, 1994; Donn, 1989; Edmondson, 1989; Entwistle & Ramsden, 1983).

It also appears from Table 9 that there is no interaction ($\underline{P}$<.585) between the treatment and meaningful learning variables on students' understanding of Newton's laws.

Figure 8. Boxplot of FCI Scores VS. Rote & Meaningful Learner.



0 = Rote Learner

1 = Meaningful Learner

Table 9.

Univariate Analysis of Variance for the FCI Scores in the Treatment Groups VS. Rote Learning and Meaningful learning Students

Source	Sum of sq.	D.F.	Mean sq.	F	P
Corrected Model	422.201*	3	140.734	6.383	.001
Intercept	15126.816	1	15126.816	686.060	.000
CTI, CTGI, and CBI	412.612	2	206.306	9.357	.000
Rote/Meaningful	19.334	1	19.334	.877	.352
(Groups)(Rote/Meaningful)	24.049	2	12.025	.540	.585
Error	1896.199	86	22.049		
Total	20466.000	90			
Corrected Total	2318.400	89			

* R Squared = .182

Table 10.

Descriptive Statistics for the FCI Scores in the Treatment Groups VS. Rote Learning and Meaningful learning Students

Groups	Rote/Meaningful	Mean	Std. Deviation	N
CTI	Rote Student	11.4444	2.1279	9
	Meaningful Student	11.8571	4.8506	21
	Total	11.7333	4.1848	30
CTGI	Rote Student	12.0000	5.0427	8
	Meaningful Student	14.6818	5.6517	22
	Total	13.9667	5.5428	30
CBI	Rote Student	16.8182	5.1346	11
	Meaningful Student	16.9474	3.7487	19
	Total	16.9000	4.2210	30
Total	Rote Student	13.7143	4.9205	28
	Meaningful Student	14.4194	5.2089	62
	Total	14.2000	5.1039	90

Table 11.

Groups Comparison for the Rote Learning and Meaningful learning Students Dependent : FCI

Group (I)	Group (J)	Means Difference (I - J)	Std. Error	95 Pct. Con.
CTI	Rote Student	11.444	1.574	8.315 - 14.574
	Meaningful Student	11.857	1.030	9.808 - 13.906
CTGI	Rote Student	12.000	1.669	8.681 - 15.319
	Meaningful Student	14.682	1.007	12.680 - 16.683
CBI	Rote Student	16.818	1.423	13.988 - 19.649
	Meaningful Student	16.947	1.083	14.794 - 19.101

CHAPTER V

Discussion and Conclusion

The discussion of the results and conclusion drawn from these results will be organized by research questions one through three.

Question One Discussion

To determine differences in the understanding of Newtonian physics by students exposed to one of the three different computer-aided instructional treatments (CTI, CTGI, and CBI).

Based on effect size, a difference in ability to respond to test items did exist between CTI, CTGI, and CBI groups. The nature of the instructional design and method appeared to have more to do with the results than any other factor accounted for in this study. Perhaps a more defined distribution would have occurred if the learners were assessed according to learning style or type of intelligence within each treatment group. It would appear that students not possessing an enhanced spatial intelligence found two-dimensional drawings (CTGI) incomplete. The CTI format would also limit the non-spatial student—perhaps to an even greater degree. However, the CBI format provided the spatial and non-spatial students with all they needed to succeed. An animation of the actual teaching point was clearly displayed and then tested. These results are generally consistent with other studies reported in literature (Aiello & Wolfle, 1980; Kulik & Kulik, 1991; Roblyer, Castine, & King, 1988; Wise, 1989; Gardner, 1993).

Computer-based instruction, if designed correctly, will incorporate features that attract all learning styles. Animations or video clips are certainly the most dynamic teaching tools, but are only pieces of the cognitive puzzle. CBI uses the strength of textual information, which in this study existed exclusively in the CTI format, to probe the memory and experiences of each student. The students cognitively interacted with the information on the screen by combining past perceptions of the world around them with the current information on Newton's laws introduced by the CBI treatment. Simple graphics, a design feature used in this study's CTGI format, enhanced the CTGI and CBI presentations by helping the students to have the same frame of reference. But where CBI pulls ahead of CTI and CTGI is in its ability to combine text, graphics, and animations during the instruction phase to more completely explain physics concepts.

Question Two Discussion

To determine and investigate the differences among reasoning ability, treatment (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws.

A 2 x 3 analysis of variance (ANOVA) was performed comparing the means of reasoning ability (concrete and formal) of students and the means of the treatments (CTI, CTGI, and CBI). There was not a significant difference among reasoning ability of students and the treatments as measured by the scores of the FCI.

This finding contradicts the results of others that suggested that students who had high reasoning ability had the greatest physics understanding and fewer misconceptions (Williams & Cavallo, 1995).

There was evidence of pre-learning in the sample groups. The students exhibited a baseline rational ability (R=21.5%). The treatments built on that baseline ability in one of three ways: text only (CTI); text and graphics (CTGI); and text, graphics, and animations (CBI).

The affect of teacher/student interaction during classroom instruction was not accounted for in this study. This should not have affected the results, in that all of the students received the same amount of classroom instruction. What is purely individual is one's motivation to learn, natural cognitive ability, or life experiences. In this researcher's view accounting for these variations would be a starting point for continued research, but would not affect the results of this study.

Effect sizes distinguished differences between treatments more than any other statistical analysis. Rationality differences were not significantly different between concrete and formal groups—offering evidence that the groups were rationally homogeneous. The real difference was clearly in instructional design; with animation within the CBI format showing the greatest advantage when teaching physics concepts.

This finding also indicated that there is no interaction ($\underline{P}<.666$) between the treatment and reasoning ability variables on students' understanding of Newton's laws.

Question Three Discussion

To determine and investigate the differences among meaningful learning, treatment (CTI, CTGI, and CBI), and the interaction of these variables on students' understanding of Newton's laws.

A 2 x 3 analysis of variance (ANOVA) was performed comparing the means of meaningful learning (rote and meaningful) of students and the means of the treatments (CTI, CTGI, and CBI). There was not a significant difference among meaningful learning of students and the treatments as measured by the scores of the FCI. However, the meaningful learning students had a higher overall mean understanding of Newton's laws. In fact, the absence of significant differences between meaningful learning and the treatments support the notion that the meaningful learning variable and the rote learning variable maybe independent from each other. This finding is not consistent with the work of other researchers who found that the greater the student's meaningful learning approach, the greater the physics concepts understanding (Williams & Cavallo, 1995) and that the meaningful learners performed significantly better than the rote learners on the misunderstandings posttest in chemistry (Boujaoude, 1992).

The student may implement a combination of both meaningful and rote approaches to learning in order to accomplish the given assignment. Choice of learning approach may be more situational and contextual than has been considered in the literature previously (Saunders, 1998). Another interpretation of this finding is that the test (LAQ) in this research had a close range of scores that were possible for students to attain. The close range makes it unlikely to find statistically significant results. Although the original sample size was 180, these analyses were conducted on a reduced number of students (90), owing to incompleteness and outliers. Nevertheless, this issue is one that unfortunately cannot be resolved in most educational research.

Conclusions

Some educators and teachers have questioned the way traditional curricula have been carried out in the schools. Meanwhile, most of the literature on teaching physics stresses experiments and demonstrations that are very helpful to students who have a willingness to learn physics concepts. However, there is less debate about modeling the content and delivery of physics curricula to become more attractive to students who lack an interest in physics concepts (Knupfer & Zollman, 1994).

The conceptual understanding of Newton's laws as measured by the Force Concept Inventory (FCI) scores was significantly increased for students who interacted with computer-based instruction with animation within the CBI format. Effect sizes of approximately 1.2 were found. It is evident that the use of animation in teaching Newtonian physics can improve students' overall concept understanding of physics. The computerized visual animation in the CBI helped physics students develop better understanding of Newtonian physics concepts. These findings are consistent with the current literature that studies that computerized visual animation makes concepts more accessible to science students (Escalada, Rebello, & Zollman, 1996).

These results suggest that the use of animation in computer-based instruction embedded in the curricula can be a very important part of teaching. Further research is needed to confirm these finding in different contexts and with larger sample.

Suggestion for Further Research

Several suggestions from this study are worth investigating for further research:

1. Long term retention (remembering) of conceptual understanding from the treatment with CBI.

2. Repeating this experiment with more complex topics (i.e., Electromagnetic forces) to determine the effect of conceptual understanding from the treatments (CTI, CTGI, and CBI).

3. Repeating this experiment at the high school level to determine the effect of conceptual understanding from the treatments (CTI, CTGI, and CBI).

4. Consider adding a later follow-up test to measure the effect of conceptual understanding from the treatment with CBI.

5. Repeating this experiment to investigate the effect of conceptual understanding of physics from the treatments with the FCI and open-ended questions to determine how students' responses differ by gender.

Previous research relating to film, video, motion pictures, and virtual animation indicates that these media are indeed an effective tool of learning. Further research should look at the effect of interaction between the learner and the computer technology to enhance the learning. By allowing the students to choose the order of presentation on the computer, the learner becomes involved with the meaning and content of the lesson itself.

REFERENCES

Aiello, N.C., & Wolfle, L.M. (1980, April). A meta-analysis of individualized instruction in science. Paper presented at the Annual Meeting of the American Educational Research Association, Boston, MA. (ERIC Document Reproduction Service No. ED 190 404)

Alexander, M. P. (1993). The effective use of computer and graphing calculators in college algebra, Georgia State University, Dissertation abstract Order No. AAAC 9328010.

Atkin, J.A. (1977). An information processing model of learning and problem solving. Unpublished master's thesis, Cornell University, Ithaca, NY.

Bitner, B. L. (1991). Formal operational reasoning modes: Predictors of critical thinking abilities and grades assigned by teachers in science and mathematics for students in grades nine through twelve. Journal of Research in Science Teaching, 28(3), 265-274.

BouJaoude, S.B. (1992). The relationships between high school students' learning strategies and the change in their misunderstandings during a high school chemistry course. Journal of Research in Science Teaching, 29(7), 687-699.

Brown, D. E. & Clement J., (1989). Overcoming misconception via analogical reasoning: Abstract transfer versus explanatory model construction. Instructional Science, 18, 237-261.

Campbell, D.T. & Stanley, J.C., (1963). Experimental and quasi-experimental designs for research. USA: Rand McNally & Company.

Cavallo, A.M.L., (1996). Meaningful learning, Reasoning ability, and students' understanding and problem solving of topics in genetics. Journal of Research in Science Teaching, 33, 625-656.

Cavallo, A.M.L. (1994). Do females learn biological topics by rote more than males? The American Biology Teacher, 56, 348-352.

Cavallo, A. L. (1991). The relationships between students' meaningful learning orientation and their mental models of meiosis and genetics. Dissertation abstracts international, 52, 2877A. (University Microfilms No. AAC92-04496) Syracuse University, Syracuse, NY.

Cavallo, A.M.L., & Schafer, L.E. (1994). Relationships between students' meaningful learning orientation and their understanding of genetics topics. Journal of Research in Science Teaching, 31, 393-418.

Clement, J. (1987). Overcoming students' misconceptions in Physics: The role of anchoring intuitions and analogical validity. Proceedings of the second international seminar. Cornell University, USA. Volume III.

Cracolice, M. S. (1994). An investigation of computer-assisted instruction and semi-programmed instruction as a replacement for traditional recitation/discussion in general chemistry and their relationships to student cognitive characteristics. Doctoral Dissertation, The University of Oklahoma.

Dechsri, P., & Jones, L. L. & Heikkinen, H. W., (1997). Effect of a laboratory manual design incorporating visual information-processing aids on student learning and attitudes . Journal of Research in Science Teaching, 34, 891-904.

Dickie, L. O. (1994). Approach to learning and assessment in physics. (Distribution number 1532 0521) Report presented to Ministry of Higher Education and Science: John Abbott College, Quebec, Canada.

DiSessa, A. (1982). Unlearning Aristotelian physics: A study of knowledge-based learning. Cognitive Science, 6, 37-75.

Donn, S. (1989,). Epistemological issues in science education. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Edmonson, K.M. (1983, March). Differences and similarities between males' and females' conceptions of scientific knowledge and their orientations to learning. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Entwistle, N., & Ramdsen, P. (1983). Understanding student learning. London: Croom Helm.

Entwistle, N., & Waterston, S. (1988). Approaches to studying and levels of processing in university students. British Journal of Educational Psychology, 58, 258-265.

Escalada , L. T., & Zollman, D. A. (1997). An investigation on the effect of using Interactive Digital Video in a physics classroom on student learning and attitudes . Journal of Research in Science Teaching, 34, 467-489.

Faryniarz, J. V. (1992). Effectiveness of microcomputer simulation in stimulating environmental problem solving by community college students. Journal of Research in Science Teaching, 29(5), 453-470.

Fletcher, J. D., & Hawley, D. E., & Piele, P. K., (1990). Cost, effects, and utility of microcomputer assisted instruction in the classroom. American Educational Research Journal, 27, 783-806.

Flick, L. B. (1990). Interaction of intuitive physics with computer simulated physics. Journal of Research in Science Teaching, 27(3), 219-231.

Fredenbery, V. G. (1993). Supplemental visual computer-assisted instruction and students achievement in freshman college calculus visualization. Dissertation abstract Order No. AAC 9417924.

Gardner, H., (1993). Frames of Mind: The Theory of Multiple Intelligences. New York, NY: BasicBooks.

Guzdial, M. (1994). Approaches to Classroom-Based Computational Science. Paper presented at the annual meeting of the National Educational Computing Conference, Boston, MA.

Hays, T. A. (1994). Spatial ability and the effect of computer animation on short term comprehension and long term conceptual understanding. Dissertation abstracts international, 55, 2877A. University of Oklahoma, Norman, OK.

Haertel, H. (1990). Lernenund Verstehen physikalischer Konzepte. Pp. 79. IPN, Kiel.

Hammer, D. (1989). Two approaches to learning physics. The Physics Teacher, 27(9), 664-670.

Hestenes, & Wells, & Swackhamer (1992). Force Concept Inventory. The physics teacher, 30(3), 141-158.

Hewitt, P. G. (1995). Lessons from lily on the introductory course. Physics Today, 48(9), 85-86.

Hewson, P.W., & Hewson, M.G, (1984). The role of conceptual conflict in conceptual conflict change and the design of science instruction. Instructional Science, 13, 1-13.

Jonassen, D. H., (1996). Computer in the classroom: mindtools for critical thinking. Columbus, OH: Prentice Hall.

Knupfer, & Zollman (1994). Using DVI to teach physics: Making the abstract more concrete. Paper presented at the annual meeting of the National Convention of the Association for Educational Communications and Technology, Nashville, TN.

Koballa, T.R., Crawley, F.E., & Shrigley R.L. (1990). A summary of research in science education-1988. Science Education, 74(3).

Kommers, P., Jonassen, D. H. & Mayes, T., eds. (1992). Cognitive tolls for learning. Berlin: Springer.

Krajcik, J. S., Simmons, P. E., & Lunetta, V. N. (1988). A research strategy for the dynamic study of students' concepts and problem solving strategies using science software. Journal of Research in Science teaching, 25(2), 147-155.

Kulik, C-L. C., & Kulik, J.A. (1991).Effectiveness of computer based instruction: An updated analysis. Computers in Human Behavior, 7(1-2), 75-94.

Lawson, A.E., & Renner, J.W. (1975). Relationships of science subject matter and developmental levels of learners. Journal of Research in Science Teaching, 12(4), 347-358.

Lawson, A.E., & Thompson, L.D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. Journal of Research in Science Teaching, 25, 733-746.

Linn, M. C. (1988). Science education and the challenge of technology. In: Information Technologies and Science Education 1988 Yearbook of the AETS, ERIC Clearinghouse for Science, Math, and Environmental Education.

Lowery, B. A. H. (1989). A comparison of computer-assisted instruction and traditional lecture/discussion and their relationships to students cognitive style, faculty and student time involvement, and cost (Doctoral dissertation, University of Alabama, 1988). Dissertation abstracts international, 49(10), 2914A-2915A.

Marek, E.A. & Cavallo, A.M.L., (1997). The Learning Cycle: Elementary School Science and Beyond. Portsmouth, NH: Heinemann.

Minstrell, J. (1989) Teaching Science for Understanding. In: (eds. I., Resnick & L. Klopfer) ASCD Yearbook: Toward the Thinking Curriculum. Association for Supervision and Curriculum Development 1989.

Novak, J.D. (1988). Learning science and the science of learning. Studies in Science Education, 15, 77-101.

Osborne, R.J., & Wittrock, M.C. (1983). Learning Science: a generative process. Science Education, 67(4), 489-508.

Park, O. C. & Gittelman, S. S. (1992). Selective use of animation and feedback in computer based instruction. Educational technology research and development, 40, 413-423.

Pea, R.D. (1985). Beyond amplification: Using the computer to reorganize mental functioning. Educational psychologist, 20 (4), 167-182.

Piaget, J. (1964). Development and learning. Journal of Research in Science Teaching, 2, 176-186.

Ramsden, P., & Entwistle, N. J. (1981). Effects of academic departments on students' approaches to studying. British Journal of Educational Psychology, 51(3), 368-383.

Renner, J.W (1985). The learning cycle and secondary school teaching. Norman, Oklahoma: University of Oklahoma Press.

Renner, J.W., & Marek, E.A. (1988). The learning cycle and elementary school science teaching. Portsmouth, NH: Heinemann.

Renner, J. W., Stafford, D. G. Lawson, A. E. McKinnon, J. W. Friot, F. E. Kellogg, D. H., (1976). Research, teaching, and learning with the Piaget model. University of Oklahoma press; Norman, OK.

Reiner, M. & Shauble, L. (1990). Knowledge structure and problem solving in electricity. In: (ed. E. Bar-On) Knowledge representation and ITS.

Rieber, L.P., (1991). Animation, incidental learning, and continuing motivation. Journal of Educational Psychology, 83, 318-328.

Rieber, L. P. (1990a). Animation in computer-based instruction. Educational Technology, Research and Development, 38(1), 77-86.

Rieber, L.P., & Parmley M. W. (1992). Effects of animated computer simulations on inductive learning with adults: A preliminary report. Journal of Educational Psychology, 31, 637-643.

Rigney, J. W., & Lutz (Alesandrini), K. A. (1976). Effect of graphic analogies of concepts in chemistry on learning and attitude. Journal of Educational Psychology, 63(3), 305-311.

Robertson, M. (1984). Use of videotape-simulated recall interviews to study the thoughts and feelings of students in an introductory biology laboratory course. Unpublished master's thesis, Cornell University, Ithaca, NY.

Roblyer, M.D., Castine, W.H., & King, F.j. (1988). Assessing the impact of computer based instruction: A review of recent research. Computers in the Schools, 5(3/4), 11-149.

Saunders, G. L. (1998). Relationships among eipistemological beliefs, implementation of instruction, and approaches to learning in college chemistry. Dissertation Abstracts International, 98, 39804. University of Oklahoma, Norman, OK.

Simpson, W.D., & Marek, E.A. (1988). Understanding and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. Journal of Research in Science Teaching, 25(5), 361-374.

Smith, C., Snir, J., & Grosslight, L. (1987). Teaching for conceptual change using a computer-based modeling approach: The case of weight/density differentiation. (Technical Report 87-11). Cambridge, MA: Educational Technology Center. ERIC Document (ED 291 598).

Summerlin, L., & Gardner, M. (1973). A study of tutorial-type computer-assisted instruction in high school chemistry. Journal of Research in Science Teaching, 10(1),
75-82.

Tobin, & Capie, (1994). The development and validation of a group test of logical thinking. Educational and Psychological Measurement, 41, 413-423.

Von Wodtke, M., (1993). Mind over media: creative thinking skills for electronic media. New York: McGraw-Hill.

Wainright, C. L. (1989). The effectiveness of a computer-assited instruction package in high school chemistry. Journal of Research in Science Teaching, 26(4),
275-290.

Weller, H. G., (1995). Diagnosing and altering three Aristotelian alternative conceptions in dynamics: Microcomputer simulations of scientific models. Journal of Research in Science Teaching, 32, 271-290.

White, B. Y. (1984). Designing computer games to help physics students understand Newton's laws of motion. Cognition and instruction, 1, 69-108.

White, B. Y., & Frederisen, J. R. (1990). Causal model progressions as a foundation for intelligent learning environments. Artificial Intelligence, 42, 99-157.

Williams, K.A. & Cavallo, A.M.L. (1995). Relationships between reasoning ability, meaningful learning and students' understanding of physics concepts. Journal of College Science Teaching, 24(5), 311-314.

Williams, K.A. & Cavallo, A.M.L. (1994). One more reason to teach so that students don't just memorize. Paper presented at the American Association of Physics Teachers Summer Meeting, Notre Dame, IN, Aug. 10, 1994.

Williamson, V. M., & Abraham, M. R., (1995). The effect of computer animation on the particulate mental models of college chemistry students. Journal of Research in Science Teaching, 32, 521-534.

Wise, K. C. (1989). The effect of using computing technologies in science instruction: A synthesis of classroom-based research. In J.D. Ellis (ED), 1988 AETS yearbook: Information technology and science education (pp. 105-118). Association for the Education of Teachers in Science.

Woolf, B., Blegan, D., Jansen, J., & Verloop, A. (1986). Teaching a complex industrial process. Philadelphia, PA: National Association of Artificial Intelligence.

Zemansky, M.W. (1984). The initial knowledge state of college physics students. American Journal of Physics, 53, 1043-1055.

Appendix A

Permission Letter

The University of Oklahoma

OFFICE OF RESEARCH ADMINISTRATION

September 3, 1998

Mr. Hamid Baharestani
P.O. Box 3177
Norman, OK 73070

Dear Mr. Baharestani:

Your research proposal, "Relationships Among Reasoning Ability, Meaningful Learning, and Computer Based Instruction on Students' Understanding of Newton's Laws," has been reviewed by Dr. E. Laurette Taylor, Chair of the Institutional Review Board, and found to be exempt from the requirements for full board review and approval under the regulations of the University of Oklahoma-Norman Campus Policies and Procedures for the Protection of Human Subjects in Research Activities.

Should you wish to deviate from the described protocol, you must notify me and obtain prior approval from the Board for the changes. If the research is to extend beyond 12 months, you must contact this office, in writing, noting any changes or revisions in the protocol and/or informed consent form, and request an extension of this ruling.

If you have any questions, please contact me.

Sincerely yours,

Karen M. Petry
Administrative Officer
Institutional Review Board

KMP:pw
FY98-209

cc: Dr. E. Laurette Taylor, Chair, IRB
Dr. Ann M.L. Cavallo, Education

The University of Oklahoma

SCIENCE EDUCATION CENTER

Agreement to Participate

This letter is to obtain your consent to participate in a research project by Hamid Baharestani, Ph.D. student at OU, under the sponsorship of Dr. Michael R. Abraham a professor of Chemistry / science education at OU (OU, Science Education Center, Physical Sciences Bldg, Rm. 323, Norman, OK 73019, phone 405/325-4981). The research is to be conducted at OU (Physics Department) for four weeks. Please read all of this agreement carefully and sign if you agree to participate.

The purpose of this research is to better understand the nature and extent of students' understandings and misunderstandings of Newtonian physics using computer aided instruction. The participants of the study will be asked to complete a multiple choice test on forces before and after relevant learning experience on the computer. The participants' reasoning ability and approaches to learning will be assessed through questionnaires in order to better understand students' learning processes.

The information obtained through your participation in this research will help in developing better learning experiences for future physics students, both at OU and university cross the nation. Thus, your participation affords an opportunity to contribute to the improvement of college physics education at a national level.

This is to certify that I, ______________________ , hereby agree to participate as a
(print full name)
volunteer in a scientific investigation as a part of an authorized research program of the University of Oklahoma Science Education Center. I understand that this allows my scores to be used in research, and that my name will not be used in any reports of this research.

I understand and was told that I am free to refuse to participate in any part of this project without prejudice or detriment to me. I understand that by signing this form, I agree to participate in this research, however, this does not waive my legal rights. I understand that the faculty of the OU Science Education Center or Hamid Baharestani will answer any questions I have relating to the research procedures.

________________________ ________________________

Date Subject's signature

Appendix B

Physics Conceptual Questions

ANSWER SHEET

Initials: ___/___/___
I.D. #: ___________
Birth date: ___________
Gender: ___________
Class Section: ___________
Date: ___________

DIRECTIONS:

A series of 20 questions is presented. Record the answer you have chosen in this answer sheet. Please be assured that your answers are strictly confidential and will not be graded against you.

Question:

1. _______
2. _______
3. _______
4. _______
5. _______
6. _______
7. _______
8. _______
9. _______
10. _______
11. _______
12. _______
13. _______
14. _______
15. _______
16. _______
17. _______
18. _______
19. _______
20. _______

Physics Conceptual Questions

Answers:

1. E	**11. E**
2. A	**12. B, D**
3. B	**13. A**
4. D	**14. A**
5. B	**15. C**
6. E	**16. B**
7. A	**17. C**
8. D	**18. B**
9. C	**19. B**
10. B	**20. E**

In items 12 a subject needs to have both the answer B and D correct.

Physics Conceptual Questions

1. Two metal balls are the same SIZE, but one weighs twice as much as the other. The balls are dropped from the top of a two story building at the same time. The time It takes the balls to reach the ground below will be

a. about half as long for the heavier ball.
b. about half as long for the lighter ball.
c. about the same time for both balls.
d. considerable less for the heavier ball, but not necessarily half as long.
e. considerably less for the lighter ball, but not necessarily half as long.

2. Imagine a head-on collision between a large truck and a small compact car. During the collision,

a. the truck exerts a greater amount of force on the car than the car exerts on the truck.
b. the car exerts a greater amount of force on the truck than the truck exerts on the car.
c. neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
d. the truck exerts a force on the car, but the car doesn't exert a force on the truck.
e. the truck exerts the same amount of force on the car, as the car exerts on the truck.

3. Two steel balls, one of which weighs twice as much as the other, roll off a horizontal table with the same speeds. In this situation,

a. both balls impact the floor at approximately the same horizontal distance from the base of the table.
b. the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
c. the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
d. the heavier ball hits considerable closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
e. the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

4. **A boy throws a steel ball straight up. Disregarding any effects of air resistance, the force(s) acting on the ball until it returns to the ground is (are):**

a. its weight vertically downward along with a steadily decreasing upward force.
b. a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
c. a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
d. a constant downward force of gravity only.
e. none of the above, the ball falls back down to the earth simply because that it its natural action.

5. **The weight of an object is**

(a) ___ the same thing as mass with different units.
(b) ___ the force produced by gravity acting on it.
(c) ___ the same on the moon as on the earth.
(d) ___ the same in outer space as on the moon or on the earth.
(e) ___ All of the above are true.

6. **Rockets and jet engines are considered to be**

(a) ___ inertial engines.
(b) ___ frictional engines.
(c) ___ reciprocating engines.
(d) ___ gravitational engines.
(e) ___ reaction engines.

7. **If we divide the weight of an object by 9.8 m/s/s, we obtain its**

(a) ___ mass.
(b) ___ velocity.
(c) ___ density.
(d) ___ acceleration.
(e) ___ coefficient of friction.

8. **Newton's third law is sometimes called the**

(a) ___ law of inertia.
(b) ___ law of motion.
(c) ___ law of gravity.
(d) ___ law of reaction.
(e) ___ law of equilibrium.

9. When a moving car is brought to a stop with the brakes, it was stopped by

(a) ___ the force the car exerted on the road.
(b) ___ the force exerted on the brake pedal.
(c) ___ the force the road exerted on the car.
(d) ___ the inertia of the wheels.
(e) ___ the force exerted by gravity on the car.

10. Object 1 has mass M whiles objects 2 has mass 2M. If equal forces are applied to each, we may state that

(a) ___ object 1 has twice the acceleration of object 2.
(b) ___ object 2 has twice the acceleration of object 1.
(c) ___ equal forces will produce the same acceleration for each.
(d) ___ object 1 has 4 times the acceleration of object 2.
(e) ___ object 2 has 1.41 times the acceleration of object 1.

11. An object is moving north at constant speed. We can state that

(a) ___ the net force is towards the north.
(b) ___ the net force is towards the south.
(c) ___ all the forces are zero.
(d) ___ the net force is either east or west.
(e) ___ the net force is zero.

12. A stone falling from the roof of a single story building to the surface of the earth;

a. reaches its maximum speed quite soon after release and them falls at constant speed thereafter.
b. speeds up as it falls, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.
c. Speeds up because of the constant gravitational force acting on it.
d. falls because of the intrinsic tendency of all objects to fall toward the earth.
e. falls because of a combination of the force of gravity and the air pressure pushing it downward.

13. If an object has constant velocity in one direction and constant acceleration in a perpendicular direction, its path will be a

(a) ___ parabola.
(b) ___ circle.
(c) ___ ellipse.
(d) ___ hyperbola.
(e) ___ this motion is physically impossible.

14. If two vectors, each of length L, are added together, the length of the sum vector must be

(a) ___ between 0 and 2L.
(b) ___ greater than L.
(c) ___ greater than 2 L.
(d) ___ equal to 1.5L.
(e) ___ between 1.4L and 2.82L.

15. The initial velocity of a projectile is V which produces a range R. If the initial velocity is increase to 2V while the angle is unchanged, the range will be

(a) ___ 2R.
(b) ___ 3R.
(c) ___ 4R.
(d) ___ R.
(e) ___ 1.41R.

16. Object A is projected horizontally at 10 m/s from the top of a building at the same moment that object B is dropped from the same point. If the ground around the building Is level

(a) ___ object A will strike the ground first.
(b) ___ both will reach the ground at the same time.
(c) ___ object B will be first.
(d) ___ a and c are correct.
(e) ___ the correct answer cannot be determined since the height of the
building is not given.

17. Which of the following remains constant in projectile motion?

(a) ___ The range.
(b) ___ The height.
(c) ___ The horizontal component of the velocity.
(d) ___ The vertical component of the velocity .
(e) ___ The speed

18. The area under a velocity versus time curve is equivalent to the

(a) ___ maximum velocity.
(b) ___ displacement.
(c) ___ minimum acceleration.
(d) ___ maximum acceleration.
(e) ___ It has no physical significance.

19. If an object has constant acceleration, its

(a) ___ displacement changes at a constant rate.
(b) ___ velocity changes at a constant rate.
(c) ___ acceleration changes at a constant rate.
(d) ___ displacement can never be zero.
(e) ___ velocity can never be zero.

20. While studying falling objects, Galileo concluded that

(a) ___ objects fall with an acceleration that is proportional to mass.
(b) ___ objects fall with an acceleration that is proportional to weight.
(c) ___ heavy object fall proportionally faster than light objects.
(d) ___ light objects fall proportionally more slowly than heavy objects.
(e) ___ all objects fall with the same acceleration.

- All questions were taken from the Force Concept Inventory and the Test Item File: Contemporary College Physics .

Appendix C

The Force Concept Inventory

ANSWER SHEET

Initials: ___/___/___
I.D. #: ___________
Birth date: ___________
Gender: ___________
Class Section: ___________
Date: ___________

DIRECTIONS:

A series of 27 questions is presented. Record the answer you have chosen in this answer sheet. Please be assured that your answers are strictly confidential and will not be graded against you.

Question:

1. _______
2. _______
3. _______
4. _______
5. _______
6. _______
7. _______
8. _______
9. _______
10. _______
11. _______
12. _______
13. _______
14. _______
15. _______
16. _______
17. _______
18. _______
19. _______
20. _______
21. _______
22. _______
23. _______
24. _______
25. _______
26. _______
27. _______

Force Concept Inventory

Answers:

1. E	11. E	21. D
2. A	12. B, D	22. D
3. B	13. A	23. D
4. D	14. A	24. E
5. B	15. C	25. B
6. E	16. B	26. B
7. A	17. C	27. A
8. D	18. B	
9. C	19. B	
10. B	20. E	

In items 12 a subject needs to have both the answer B and D correct.

Forces Conceptual Questions

1. Two metal balls are the same SIZE, but one weighs twice as much as the other. The balls are dropped from the top of a two story building at the same time. The time it takes the balls to reach the ground below will be

a. about half as long for the heavier ball.
b. about half as long for the lighter ball.
c. about the same time for both balls.
d. considerable less for the heavier ball, but not necessarily half as long.
e. considerably less for the lighter ball, but not necessarily half as long.

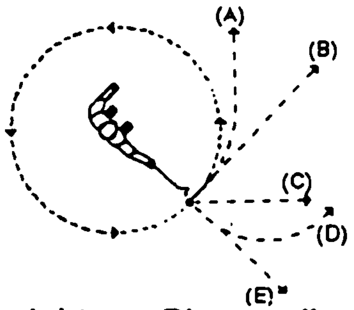
2. Imagine a head-on collision between a large truck and a small compact car. During the collision,

a. the truck exerts a greater amount of force on the car than the car exerts on the truck.
b. the car exerts a greater amount of force on the truck than the truck exerts on the car.
c. neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
d. the truck exerts a force on the car, but the car doesn't exert a force on the truck.
e. the truck exerts the same amount of force on the car, as the car exerts on the truck.

3. Two steel balls, one of which weighs twice as much as the other, roll off a horizontal table with the same speeds. In this situation,

a. both balls impact the floor at approximately the same horizontal distance from the base of the table.
b. the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
c. the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
d. the heavier ball hits considerable closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
e. the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

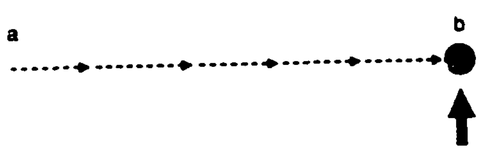
4. **A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram on the right. At the point indicated I the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.**



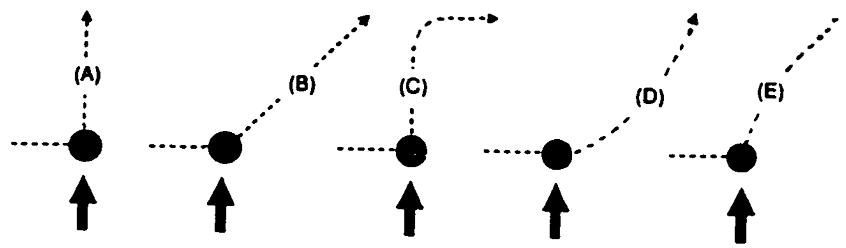
5. **A boy throws a steel ball straight up. Disregarding any effects of air resistance, the force(s) acting on the ball until it returns to the ground is (are):**

a. its weight vertically downward along with a steadily decreasing upward force.
b. a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
c. a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
d. a constant downward force of gravity only.
e. none of the above, the ball falls back down to the earth simply because that it its natural action.

Use the statement and diagram below to answer the next four question: The diagram depicts a hockey puck sliding, with constant velocity, from point "a" to point "b" along a frictionless horizontal surface. When the puck reaches point "b", it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.



6. **Along which of the paths will the hockey puck move after receiving the "kick"?**



7. **The speed of the puck just after it receives the "kick"?**

a. Equal to the speed "Vo" it had before it received the "kick".
b. Equal to the speed "V" it acquires from the "kick", and independent of the speed "Vo".
c. Equal to the arithmetic sum of the speeds "Vo" or "V".
d. Smaller than either of speeds "Vo" or "V".
e. Greater than either of the speeds "Vo" or "V", but smaller than the arithmetic sum of these two speeds.

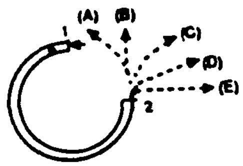
8. **Along the frictionless path you have chosen, how does the speed of the puck vary after receiving the "kick"?**

a. No change
b. Continuously increasing.
c. Continuously decreasing
d. Increasing for a while, and decreasing thereafter.
e. Decreasing for a while, and increasing thereafter.

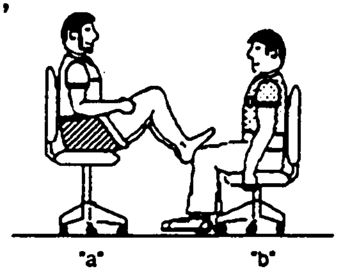
9. **The main forces acting, after the "kick", on the puck along the path you have chosen are:**

a. the downward force due to gravity and the effect of air pressure.
b. the downward force of gravity and the horizontal force of momentum in the direction of motion.
c. the downward force of gravity, the upward force exerted by the table, and a horizontal force acting on the puck in the direction of motion.
d. the downward force of gravity and an upward force exerted on the puck by the table.
e. gravity does not exert a force on the puck, it falls because of the intrinsic tendency of the object to fall to its natural place.

10. The accompanying diagram depicts a semicircular channel that has been securely attached, in a horizontal plane, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top?



11. Two students, a student "a" who has a mass of 95 kg and a student "b" who has a mass of 77 kg sit in identical office chairs facing each other. Student "a" places his bare feet on student "b"'s knees, as shown below. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. In this situation,



a. neither student exerts a force on the other.
b. Student "a" exerts a force on "b", but "b" doesn't exert any force on "a".
c. each student exerts a force on the other, but "b" exerts the larger force.
d. each student exerts a force on the other, but "a" exerts the larger force.
e. each student exerts the same force on the other.

12. A book is at rest on a table top. Which of the following force(s) is/are acting on the book.?

1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure.
4. A net upward force due to air pressure.

a. 1 only b. 1 and 2 c. 1, 2 and 3 d. 1, 2, and 4
e. none of these, since the book is at rest, there are no forces acting on it.

Refer to the following statement and diagram while answering the next two questions. A large truck breaks down out on the road and receives a push back into town by a small compact car.

13. While the car, still pushing on the truck, is speeding up to get up to cruising speed,

a. the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
b. the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
c. the amount of force of the car pushing against the truck is greater than that of the truck pushing back against the car.
d. the car's engine is running so it applies a force as it pushes against the truck, but the truck's engine is not running so it can't push back against the car, the truck is pushed simply because it is in the way of the car.
e. neither the car nor the truck car exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

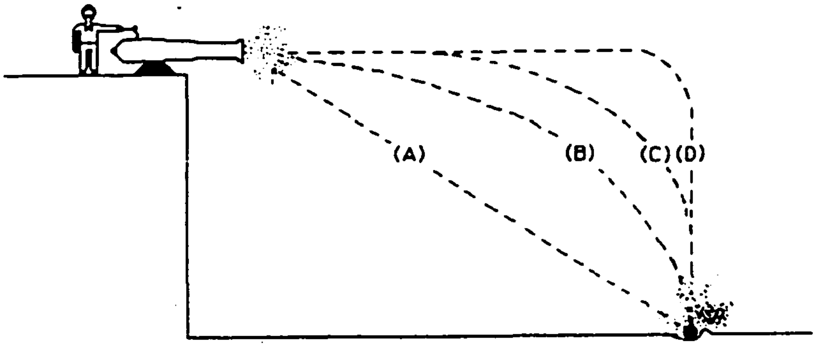
14. After the person in the car, while pushing the truck, reaches cruising speed at which he/she wishes to continue to travel at constant speed;

a. the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
b. the amount of force of the car pushing against the truck is less tan that of the truck pushing back against the car.
c. the amount of force of the car pushing against the truck is greater than that of the truck pushing back against the car.
d. the car's engine is running so it applies a force as it pushes against the truck, but the truck's engine is not running so it can't push back against the car, the truck is pushed simply because it is in the way of the car.
e. neither the car nor the truck car exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

15. When a rubber ball dropped from rest bounces off the floor, its direction of motion is reversed because:

a. energy of the ball is conserved.
b. momentum of the ball is conserved.
c. the floor exerts a force on the ball that stops its fall and then drives it upward.
d. the floor is in the way and the ball has to keep moving.
e. none of the above.

16. Which of the paths in the diagram below best represents the path of the cannon ball?

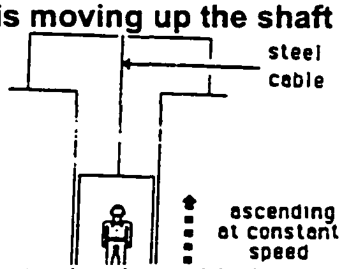


17. A stone falling from the roof of a singie story building to the surface of the earth;

a. reaches its maximum speed quite soon after release and them falls at constant speed thereafter.
b. speeds up as it falls, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.
c. Speeds up because of the constant gravitational force acting on it.
d. falls because of the intrinsic tendency of all objects to fall toward the earth.
e. falls because of a combination of the force of gravity and the air pressure pushing it downward.

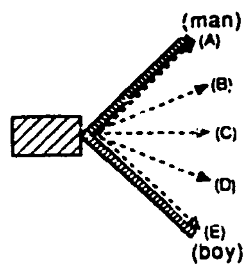
When responding to the following question, assume that any frictional forces due to air resistance are so small that they can be ignored.

18. An elevator, as illustrated, is being lifted up an elevator shaft by a steel cable. When the elevator is moving up the shaft at constant velocity;

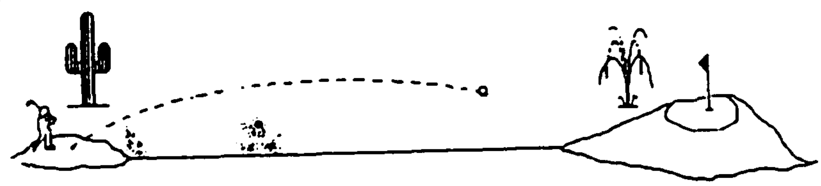


a. the upward force on the elevator by the cable is greater than the downward force of gravity.
b. the amount of upward force on the elevator by the cable is equal to that of the downward force of gravity.
c. the upward force on the elevator by the cable is less than the downward force of gravity.
d. it goes up because the cable is being shortened, not because of the force being exerted on the elevator by the cable.
e. the upward force on the elevator by the cable is greater than the downward force due to the combined effects of air pressure and the force of gravity.

19. Two people, a large man and a boy, are pulling as hard as they can on two ropes attached to a crate, as illustrated in the diagram below. Which of the indicated paths (A-E) would most likely correspond to the path of the crate as they pull it along?



20. A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the depiction below. Which of the following force(s) is/are acting on the golf ball during its entire flight?

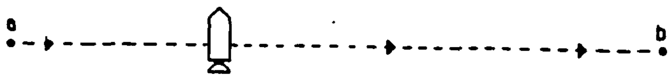


1. the force of gravity
2. the force of the "hit"
3. the force of air resistance

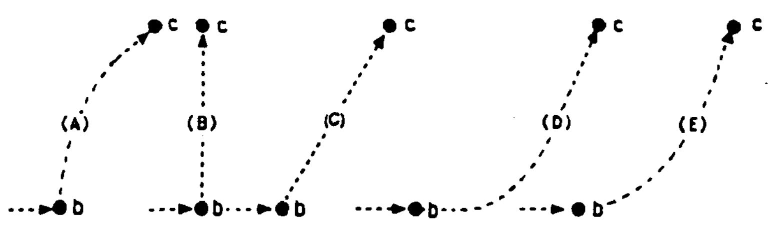
a. 1 only b. 1 and 2 c. 1, 2, and 3 d. 1 and 3 e. 2 and 3

21. A bowling ball accidentally falls out of the cargo bay of an airliner. Suppose you see this from the ground. Draw the path which the bowling ball most closely follows after leaving the airplane.

When answering the next four questions, refer to the following statements and diagram. A rocket, drifting sideways in outer space from position "a" to position "b" is subject to no outside forces. At "b", the rocket's engine starts to produce a constant thrust at right angles to the line "ab". The engine turns off again as the rocket reaches some point "c".



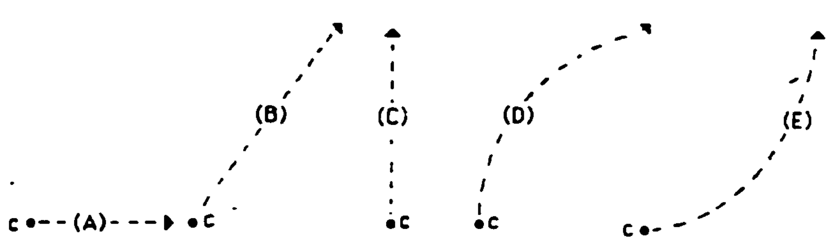
22. Which path below best represents the path of the rocket between "b" and "c"?



23. As the rocket moves from "b" to "c", its speed is

a. constant.
b. continuously increasing.
c. continuously decreasing.
d. increasing for a while and constant thereafter.
e. constant for a while and decreasing thereafter.

24. At "c", the rocket's engine is turned off. Which of the paths below will the rocket follow beyond "c"?



25. Beyond "c", the speed of the rocket is

a. constant.
b. continuously increasing.
c. continuously decreasing.
d. increasing for a while and constant thereafter.
e. constant for a while and decreasing thereafter.

26. A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box?

a. If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
b. The amount of force applied to move the box at a constant speed must be more than its weight.
c. The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional force that resists its motion
d. The amount of force applied to move the box at a constant speed must be more than the amount of the frictional force that resists its motion
e. There is a force being applied to the box to make it move but the external forces such as friction are not "real" forces, they just resist motion.

27. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will;

a. stop immediately.
b. continue at a constant speed for a very short period of time and then slow to a stop.
c. immediately start slowing to stop.
d. continue a constant velocity.
e. increase its speed for a very short period of time, then start slowing to a stop.

Appendix D

The Learning Approach Questionnaire

Background Information

Note: Please be assured that your answers are strictly confidential.

1	Initials: ___/___/___			Birth date: (mm/dd/yy) ___/___/___			
2	Age:	a 18	b 19	c 20	d 21	e Other	
3	Ethnic Origin:	a African American	b Asian American	c Caucasian/ Non Hispanic	d Hispanic American	e Native American	f Other
4	Mother's Highest Level of Education Completed:	a Less than high school	b High school graduate	c Some college	d College graduate	e Post graduate work	
5	Father's Highest Level of Education Completed:	a Less than high school	b High school graduate	c Some college	d College graduate	e Post graduate work	
6	What was your high school grade at graduation?	a A	b B	c C	d D	e F	
7	What is your grade in this science class?	a A	b B	c C	d D	e F	
8	What grade would you give yourself on your reading ability?	a A	b B	c C	d D	e F	
9	What grade would you give yourself on your ability to express yourself in writing?	a A	b B	c C	d D	e F	
10	Do you plan to take any further science courses at the university?	a Yes, definitely	b Yes, probably	c No, probably not	d No, definitely not	e Don't know	

Learning Approach Questionnaire

The following questions refer to how you study and learn about science in this class. For each item there is a five point scale ranging from "Always True" to "Never True". On the answer sheet provided, fill in the letter that best fits your IMMEDIATE reaction. Do not spend a long time on each item; your first reaction is probably the best one.

Do not worry about projecting a good image. There are no "correct" answers. Your answers are strictly confidential.

Answer every question - please do not leave any blank.

		Always True				Never True
11.	I try to relate new material, as I am learning it, to what I already know on that topic.	A	B	C	D	E
12.	I prefer to follow all "tried out" ways to solve problems rather than trying anything too adventurous.	A	B	C	D	E
13.	While I am studying, I often think of real life situations to which the material I am learning would be useful.	A	B	C	D	E
14.	I find I tend to remember things best if I concentrate on the order in which the teacher presented them.	A	B	C	D	E
15.	I find I have to concentrate on memorizing a good deal of what I have to learn.	A	B	C	D	E
16.	I go over important topics until I understand them completely.	A	B	C	D	E
17.	I find it best to accept the statements and ideas of my lectures and question them only under special circumstances.	A	B	C	D	E

		Always True				Never True
18.	In reporting laboratory work, I like to try to work out several different ways of interpreting the findings	A	B	C	D	E
19.	I often find myself questioning things that I hear in lectures or read in books	A	B	C	D	E
20.	In trying to understand new topics, I explain them to myself in ways that other people don't seem to understand	A	B	C	D	E
21.	I find it useful to get an overview of a new topic for myself, by seeing how the ideas fit together	A	B	C	D	E
22.	I set out to understand thoroughly the meaning of what I am asked to read or learn in class	A	B	C	D	E
23.	I try to relate what I have learned in one subject to that in another	A	B	C	D	E
24.	The best way for me to understand what technical terms mean is to remember the text-book definition.	A	B	C	D	E
25	I am very aware that teachers know a lot more than I do, and so I concentrate on what they say as important rather than rely on my own judgment	A	B	C	D	E
26.	I usually don't think about the implications of what is taught in class or how it relates to my life	A	B	C	D	E
27.	I learn some things by rote, going over and over them until I know them by heart	A	B	C	D	E
28.	When I'm starting a new topic, I ask myself questions about it which the new information should answer.	A	B	C	D	E
29.	Although I generally remember facts and details, I find it difficult to fit them together into an over all picture.	A	B	C	D	E
30.	When I am reading an article or listening to other's ideas in class, I generally examine the evidence carefully to decide whether the conclusion is justified.	A	B	C	D	E

Appendix E

The CTI Program

Screen # 1-10 **CTI STORYBOARD**

At the completion of this portion of the lesson, you will be able to recognize the characteristics of Newton's laws.

CONTINUE

AUDIO:

PROGRAMMING INSTRUCTIONS:

Screen # 1-20 **CTI**

Physics is theory, based on experiment. Therefore, physics is experimental science.

The study of motion is divided into two parts:

A) Kinematics, **B)** Dynamics

Kinematics-Describes the position and motion of objects in space as a function of time.

Dynamics-The study of causes of motion is called dynamics.

CONTINUE

AUDIO:

PROGRAMMING INSTRUCTIONS:

Screen # 1-30 **CTI**

Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-40 **CTI**

Average Acceleration - The change In Velocity of an object divided by the time required for that change.

Acceleration due to gravity- Galileo believed that objects fall with the same acceleration everywhere.

CONTINUE

AUDIO:

PROGRAMMING INSTRUCTIONS:

Screen # 1-50 **CTI**

Measurements show, however, that the acceleration due to gravity is approximately (9.8 m/s/s) everywhere on Earth.

This means that its speed changes at a rate of 9.8 m/s every second
Velocity = (9.8 m/s/s) time

By this equation, we can find the velocity of falling object at any instant of time.

Motion with constant acceleration- Galileo said that objects that are moving freely under the influence of gravity.

CONTINUE

AUDIO:

PROGRAMMING INSTRUCTIONS:

Screen # 1-60

CTI

Galileo released the ball from an inclined and marked its position at the end of equal intervals of time.

Galileo saw that a rolling object picks up speed as it continues to roll.

He realized that the distance traveled was proportional to the square of the elapsed time.

CONTINUE

AUDIO:

PROGRAMMING INSTRUCTIONS:

Screen # 1-70 **CTI**

FORCE (F) - A Force is a "Push" or a "Pull".

If I push a table, I exert a force on it.
We know from experience that an object at rest never starts to move by itself; a push or pull must be exerted on it by some other body.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-80 **CTI**

A force is required to slow down or stop a body already in motion.

Force has direction as well as magnitude, therefore it is a vector quantity.

If several forces acting the same time on the same object, them it is the Net force that determines the motion of the object.

∴ Net force is the vector sum of all forces acting on the object.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-90 **CTI**

Newton's first Law- In the absence of any net force a body either remains at rest or moves uniformly in a straight line. It follows that once a body has been set in motion, No force is needed to keep it moving.

Newton's Second Law- The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to the mass of the object.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-100 **CTI**

Newton's Third Law- For every action there is an equal and opposite reaction.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-110 **CTI**

The Friction Force- Friction forces arise when one object attempts to move across another.

For example, as a baseball player slides along the ground while stealing a base, there is a friction force that the ground exerts on him.

Weight- The force of gravitational exerted on every physical body by the earth is called the weight of the body.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-120 **CTI**

When an object is dropped near the earth's surface it is accelerated by the gravitational force which is equal to its weight, with an acceleration. Therefore, by Newton's Second Law the weight becomes:

$$W = m\,g$$

If we change the force of gravity on an object (by taking it to the moon), its weight will change, however its mass remains constant.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-130 **CTI**

Momentum- is defined as the product of the mass of the object and its velocity.

momentum = mass Velocity

The conservation of momentum- when two bodies interact with each other, their total momentum of the system remains constant in magnitude and direction, when the net force acting on it is zero.

CONTINUE

AUDIO:

PROGRAMMING INSTRUCTIONS:

Screen # 1-140 **CTI**

It means that momentum is conserved in collisions between objects.

If there are no external forces acting on a system, the total moment before collision equals the total momentum after .

momentum before collision = momentum after collision

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Screen # 1-150 **CTI**

Congratulation!!!

You just completed the review of this lesson.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**

Appendix F

The CTGI Program

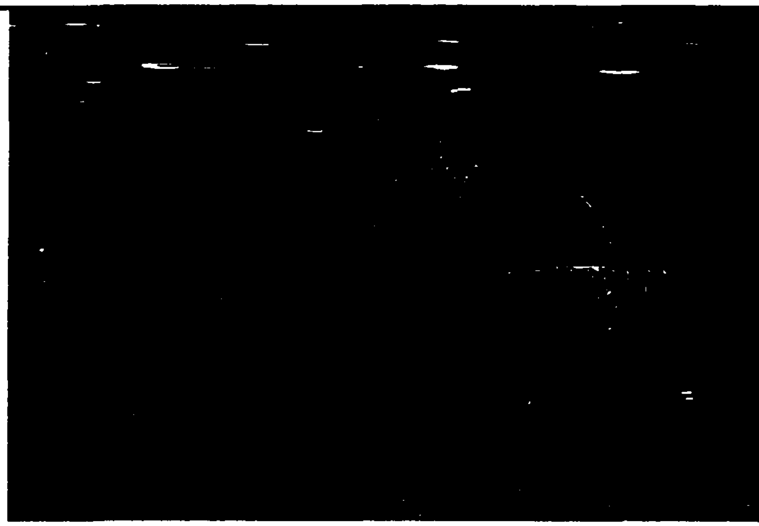
Screen # 1-10 **CTGI STORYBOARD**

At the completion of this lesson, you will be able to identify the terms and characteristics related to Newton's laws.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
At the completion of this lesson, you will be able to identify the terms and characteristics related to Newton's laws.	

Screen # 1-20 **CTGI**



Physics is an experimental science.

1) Kinematics- Describes the position and motion of objects in space as a function of time.

2) Dynamics- The study of causes of motion is called

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
Physics is theory, based on experiment. Therefore, physics is experimental science. The study of motion is divided into two parts: Kinematics, and Dynamics **Kinematics**-Describes the position and motion of objects in space as a function of time. **Dynamics**-The study of causes of motion is called dynamics.	

Screen # 1-30 CTGI

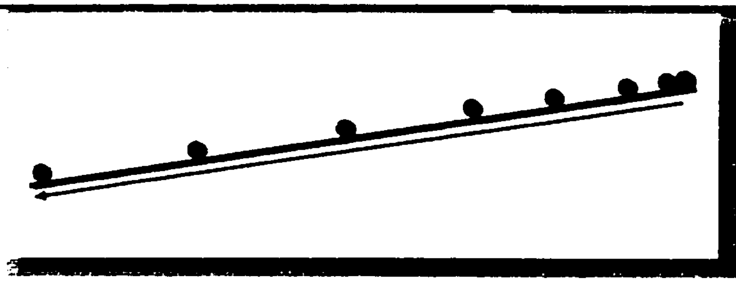
Acceleration due to gravity means that objects fall with the same acceleration everywhere.

Motion with constant acceleration means that objects that are moving freely under the influence of gravity, according to Galileo.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Acceleration due to gravity- Galileo believed that objects fall with the same acceleration everywhere. Measurements show that the acceleration due to gravity is approximately (9.8 m/s/s) everywhere on Earth. **Velocity = (9.8 m/s/s) time** **Motion with constant acceleration**- Galileo stated that objects that are moving freely under the influence of gravity.	

Screen # 1-40 **CTGI**



Galileo released the ball from an inclined and marked its position at the end of equal intervals of time.
Galileo saw that a rolling object picks up speed as it continues to roll.
He realized that the distance traveled was proportional to the square of the

CONTINUE

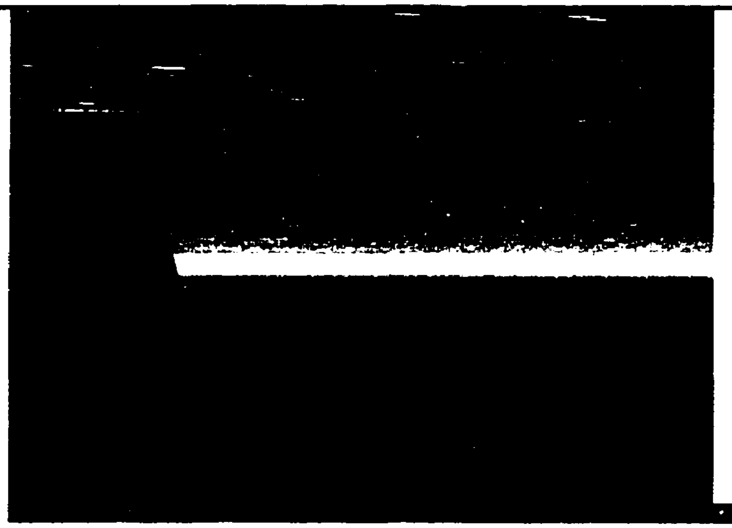
AUDIO:

Galileo released the ball from an inclined and marked its position at the end of equal intervals of time.

Galileo saw that a rolling object picks up speed as it continues to roll.
He realized that the distance traveled was proportional to the square of the elapsed time.

PROGRAMMING INSTRUCTIONS:

Screen # 1-50 **CTGI**



Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.

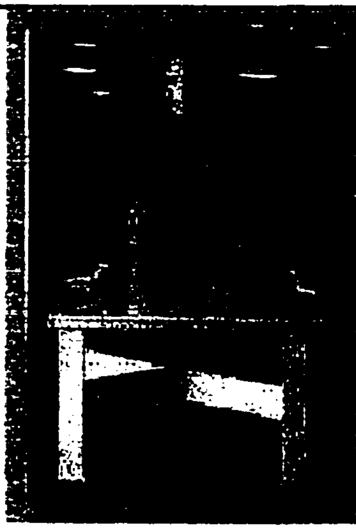
CONTINUE

AUDIO:

Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.

PROGRAMMING INSTRUCTIONS:

Screen # 1-60 **CTGI**



A Force is a "Push" or a "Pull".

An object at rest never starts to move by itself; a push or pull must be exerted on it by some other body.

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
FORCE (F) - A Force is a "Push" or a Pull". If I push a table, I exert a force on it. We know from experience that an object at rest never starts to move by itself; a push or pull must be exerted on it by some other body.	

Screen # 1-70 **CTGI**

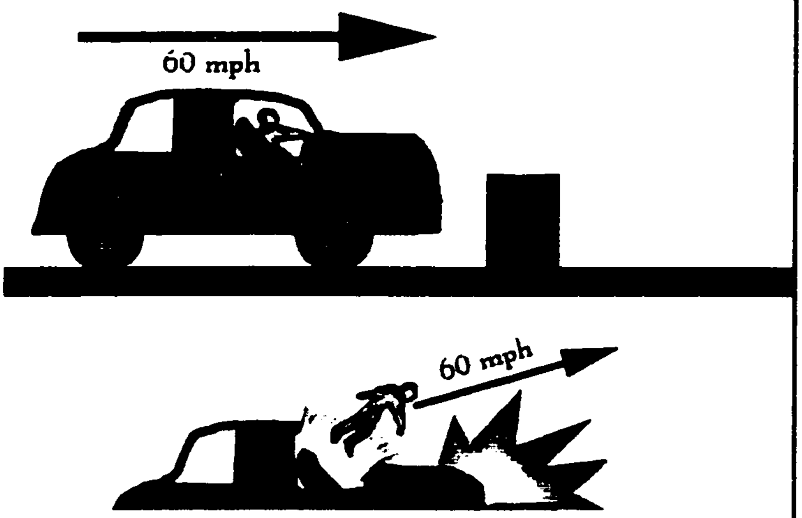
A force is required to slow down or stop a body already in motion.

If several forces are acting the same time on the same object, them it is the Net force that determines the

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
A force is required to slow down or stop a body already in motion. If several forces are acting the same time on the same object, them it is the Net force that determines the motion of the object. Therefore, Net Force is the vector sum of all forces acting on the object.	

Screen # 1-80	CTGI



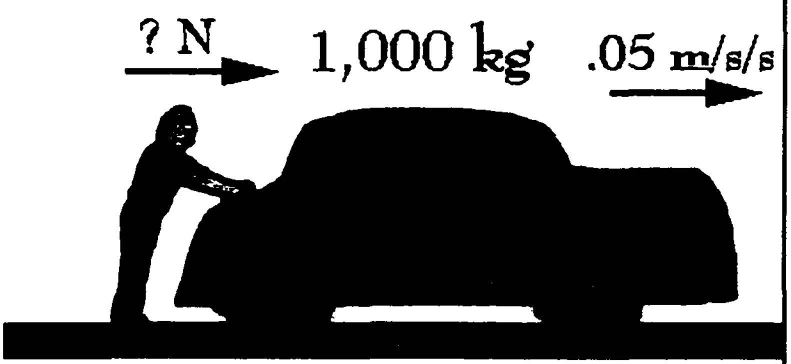
Newton's first Law -An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless the object is acted upon by an outside force.

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
Newton's first Law- An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless the object is acted upon by an outside force.	

Screen # 1-90

CTGI



Newton's Second Law - Acceleration is produced when a force acts on a mass. The greater the mass, the greater the amount of force needed to accelerate a given object.

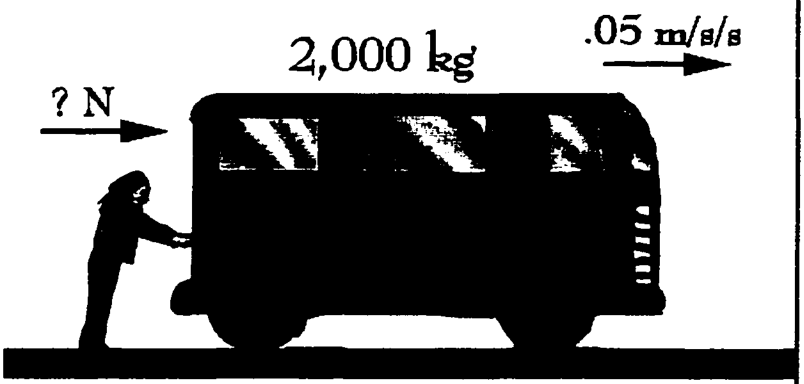
CONTINUE

AUDIO:

Newton's Second Law- Acceleration is produced when a force acts on a mass. The greater the mass, the greater the amount of force needed to accelerate a given object.

PROGRAMMING INSTRUCTIONS:

Screen # 1-100 **CTGI**



Newton's Third Law- For every action there is an equal and opposite reaction.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Newton's Third Law- For every action there is an equal and opposite reaction.	

Screen # 1-110 **CTGI**

The Friction Force - Friction forces arise when one object attempts to move across another.
Weight - The force of gravitational exerted on every physical body by the earth is called the weight of the body.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
The Friction Force- Friction forces arise when one object attempts to move across another. For example, as a baseball player slides along the ground while stealing a base, there is a friction force that the ground exerts on him. **Weight**- The force of gravitational exerted on every physical body by the earth is called the weight of the body.	

Screen # 1-120 **CTGI**

When an object is dropped near the earth's surface it is accelerated by the gravitational force which is equal to its weight, with an acceleration.

If we change the force of gravity on an object ,
its weight will change,
however Its mass remains constant.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
When an object is dropped near the earth's surface it is accelerated by the gravitational force which is equal to its weight, with an acceleration. Therefore, by Newton's Second Law the weight becomes: If we change the force of gravity on an object (by taking it to the moon), its weight will change, however its mass remains constant.	

Screen # 1-130 **CTGI**

Momentum –
is defined as the product of the mass of the object and its velocity.

momentum **= mass Velocity**

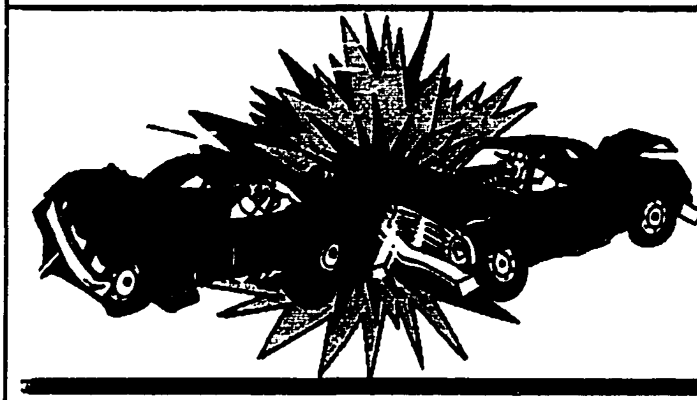
CONTINUE

AUDIO:

Momentum- is defined as the product of the mass of the object and its velocity.

PROGRAMMING INSTRUCTIONS:

Screen # 1-140 **CTGI**



The conservation of momentum- When there is no external net force on an object, if two objects collide with each other, the momentum before collision is equal to the momentum after collision.
It means that momentum is conserved in collisions between objects.

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
The conservation of momentum- When there is no external net force on an object, if two objects collide with each other, the momentum before collision is equal to the momentum after collision. It means that momentum is conserved in collisions between objects.	

Screen # 1-150 **CTGI**

Congratulation!!!

You just completed the review of this lesson.

CONTINUE

AUDIO:

Congratulation!!!
You just completed the review of this lesson.

PROGRAMMING INSTRUCTIONS:

Appendix G

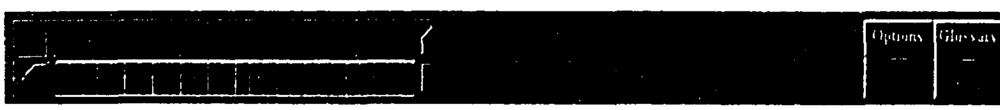
The CBI Program

Screen # 1-10

CBI STORYBOARD

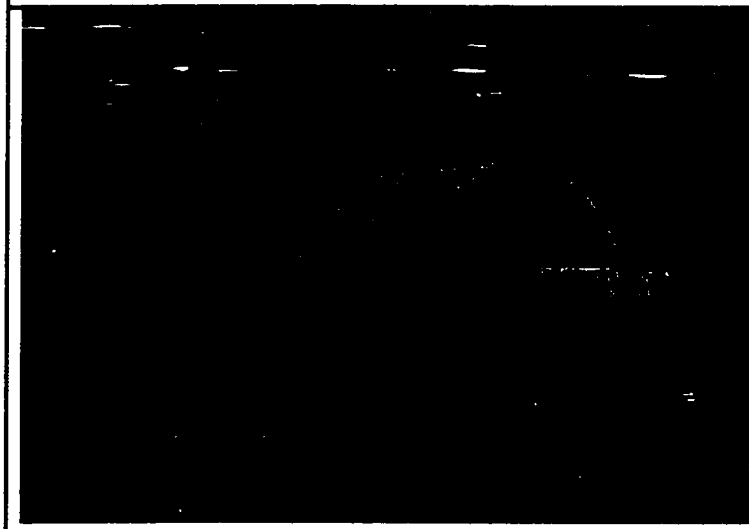
At the completion of this lesson, you will be able to identify the terms and characteristics related to Newton's laws.

CONTINUE



AUDIO:	**PROGRAMMING INSTRUCTIONS:**
At the completion of this lesson, you will be able to identify the terms and characteristics related to Newton's laws.	

Screen # 1-20 **CBI**

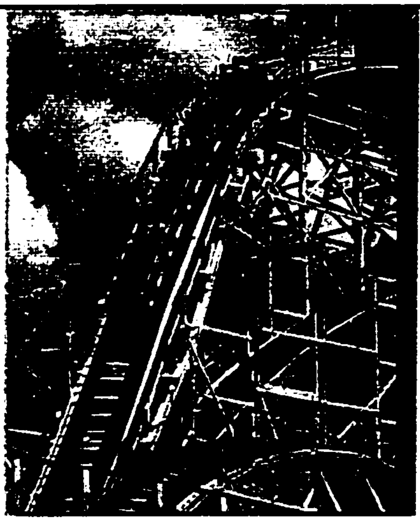


Physics is an experimental science.
1) Kinematics-
Describes the position and motion of objects in space as a function of time.
2) Dynamics-
The study of causes of motion is called dynamics.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Physics is theory, based on experiment. Therefore, physics is experimental science. The study of motion is divided into two parts: Kinematics, and Dynamics **Kinematics**-Describes the position and motion of objects in space as a function of time. **Dynamics**-The study of causes of motion is called dynamics.	

Screen # 1-30 **CBI**



Acceleration due to gravity means that objects fall with the same acceleration everywhere.

Motion with constant acceleration means that objects that are moving freely under the influence of gravity, according to Galileo.

CONTINUE

AUDIO:

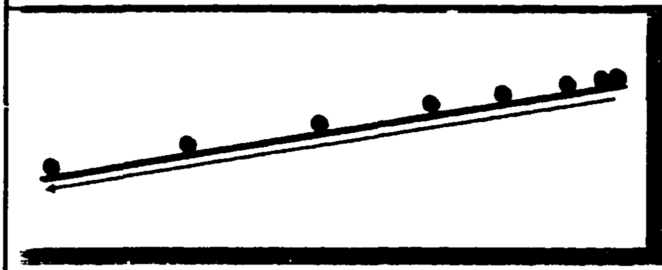
Acceleration due to gravity- Galileo believed that objects fall with the same acceleration everywhere. Measurements show that the acceleration due to gravity is approximately (9.8 m/s/s) everywhere on Earth.

Velocity = (9.8 m/s/s) time

Motion with constant acceleration- Galileo stated that objects that are moving freely under the influence of gravity.

PROGRAMMING INSTRUCTIONS:

Screen # 1-40 **CBI**



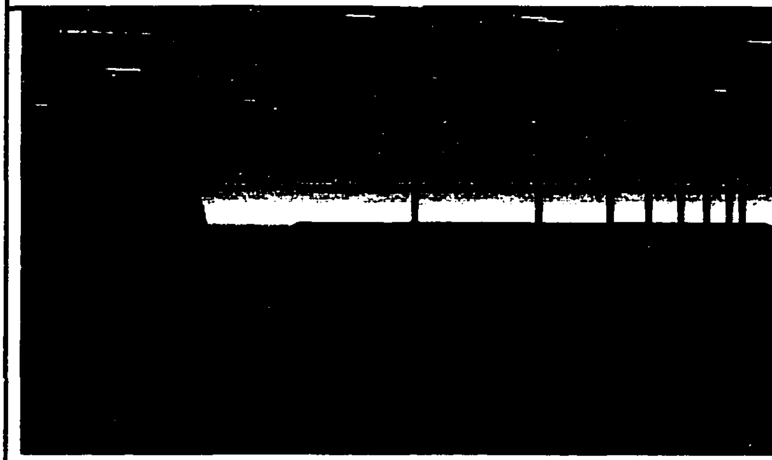
Galileo released the ball from an inclined and marked its position at the end of equal intervals of time.
Galileo saw that a rolling object picks up speed as it continues to roll.

He realized that the distance traveled was proportional to the square of the elapsed time.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Galileo released the ball from an inclined and marked its position at the end of equal intervals of time. Galileo saw that a rolling object picks up speed as it continues to roll. He realized that the distance traveled was proportional to the square of the elapsed time.	

Screen # 1-50 **CBI**



Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Projectile motion- A projectile is any object that consisting of a horizontal part with constant speed and a vertical part constant downward acceleration.	

Screen # 1-60 **CBI**

A Force is a "Push" or a "Pull".

An object at rest never starts to move by itself; a push or pull must be exerted on it by some other body.

CONTINUE

AUDIO:	PROGRAMMING INSTRUCTIONS:
FORCE (F) - A Force is a "Push" or a Pull". If I push a table, I exert a force on it. We know from experience that an object at rest never starts to move by itself; a push or pull must be exerted on it by some other body.	

Screen # 1-70 **CBI**

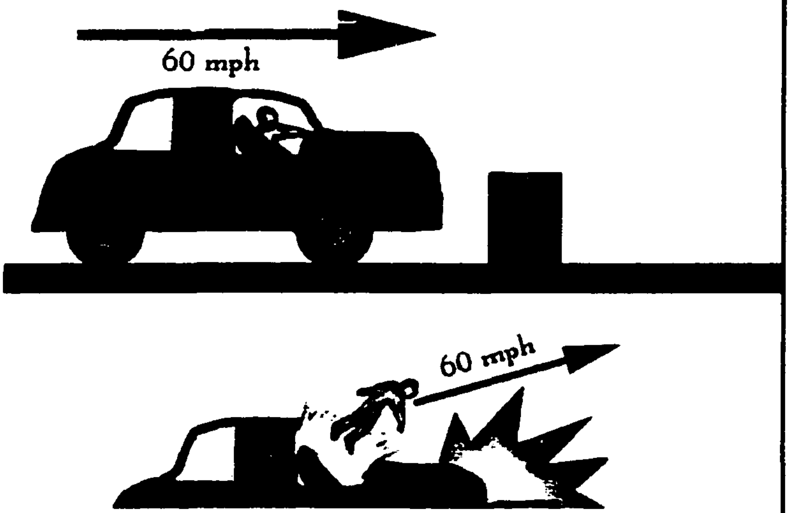
A force is required to slow down or stop a body already in motion.

If several forces are acting the same time on the same object, them it is the Net force that determines the motion of the object.

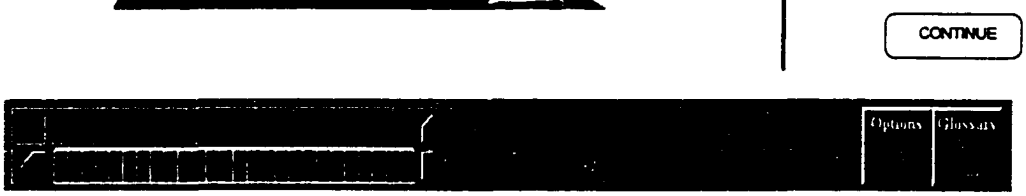
CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
A force is required to slow down or stop a body already in motion. If several forces are acting the same time on the same object, them it is the Net force that determines the motion of the object. Therefore, Net Force is the vector sum of all forces acting on the object.	

Screen # 1-80 **CBI**



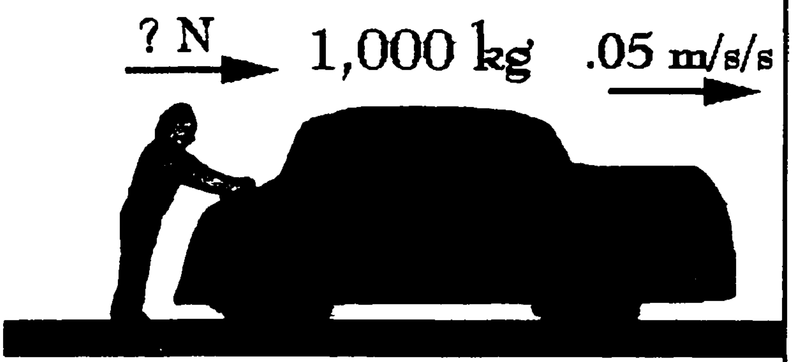
Newton's first Law -An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless the object is acted upon by an outside force.



AUDIO:	PROGRAMMING INSTRUCTIONS:
Newton's first Law- An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless the object is acted upon by an outside force.	

Screen # 1-90

CBI

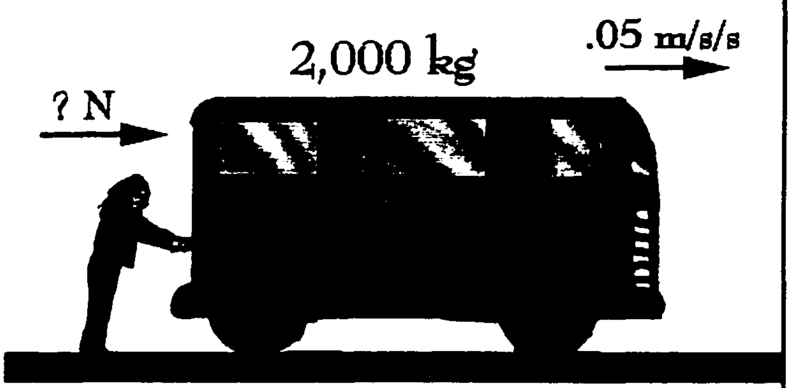


Newton's Second Law - Acceleration is produced when a force acts on a mass. The greater the mass, the greater the amount of force needed to accelerate a given object.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Newton's Second Law- Acceleration is produced when a force acts on a mass. The greater the mass, the greater the amount of force needed to accelerate a given object.	

Screen # 1-100 **CBI**



Newton's Third Law- For every action there is an equal and opposite reaction.

CONTINUE

AUDIO:

Newton's Third Law- For every action there is an equal and opposite reaction.

PROGRAMMING INSTRUCTIONS:

Screen # 1-110 **CBI**

The Friction Force - Friction forces arise when one object attempts to move across another.

Weight - The force of gravitational exerted on every physical body by the earth is called the weight of the body.

CONTINUE

AUDIO:

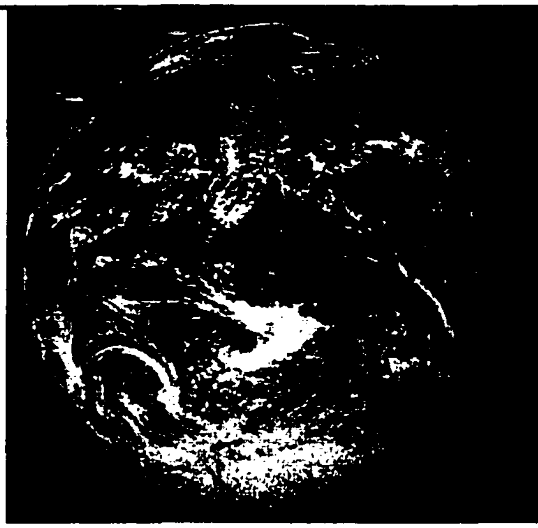
The Friction Force- Friction forces arise when one object attempts to move across another.

For example, as a baseball player slides along the ground while stealing a base, there is a friction force that the ground exerts on him.

Weight- The force of gravitational exerted on every physical body by the earth is called the weight of the body.

PROGRAMMING INSTRUCTIONS:

Screen # 1-120 **CBI**



When an object is dropped near the earth's surface it is accelerated by the gravitational force which is equal to its weight, with an acceleration.

if we change the force of gravity on an object , its weight will change, however its mass remains constant.

CONTINUE

AUDIO:

When an object is dropped near the earth's surface it is accelerated by the gravitational force which is equal to its weight, with an acceleration. Therefore, by Newton's Second Law the weight becomes:

If we change the force of gravity on an object (by taking it to the moon), its weight will change, however its mass remains constant.

PROGRAMMING INSTRUCTIONS:

Screen # 1-130 **CBI**

Momentum –
is defined as the product of the mass of the object and its velocity.

momentum = **mass**
Velocity

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Momentum- is defined as the product of the mass of the object and its velocity.	

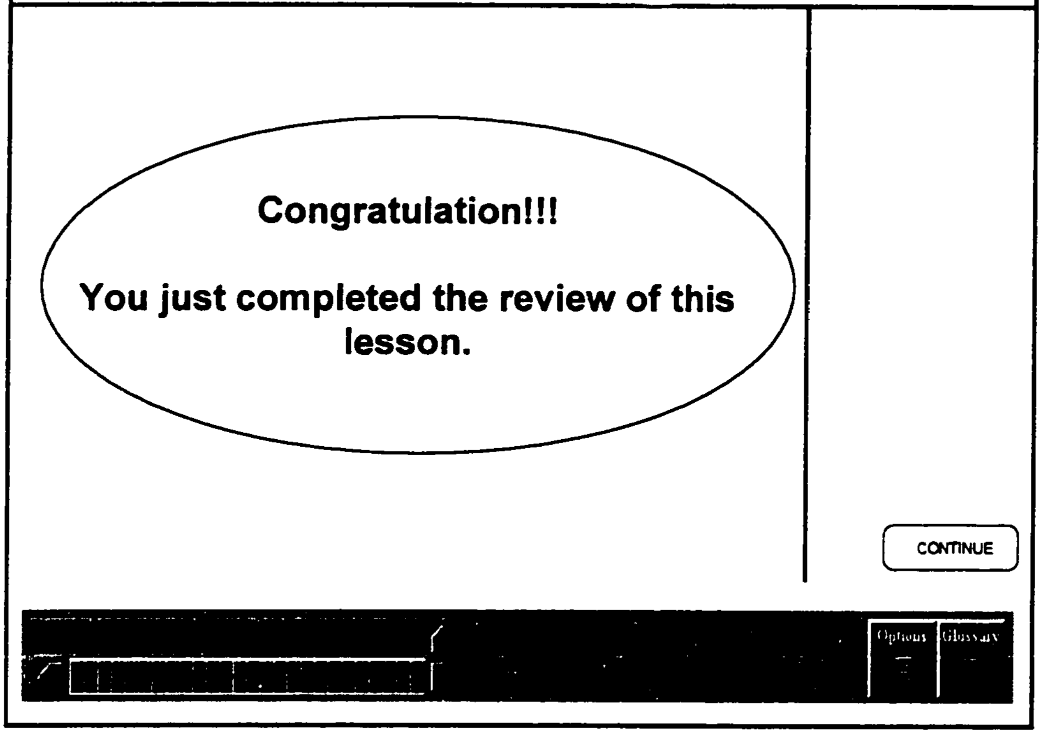
Screen # 1-140	**CBI**

The conservation of momentum- When there is no external net force on an object, if two objects collide with each other, the momentum before collision is equal to the momentum after collision.
It means that momentum is conserved in collisions between objects.

CONTINUE

AUDIO:	**PROGRAMMING INSTRUCTIONS:**
The conservation of momentum- When there is no external net force on an object, if two objects collide with each other, the momentum before collision is equal to the momentum after collision. It means that momentum is conserved in collisions between objects.	

Screen # 1-150 **CBI**



AUDIO:	**PROGRAMMING INSTRUCTIONS:**
Congratulation!!! **You just completed the review of this lesson.**	

Appendix H

Individual students' TOLT scores

Treatments:

CTI = 1, CTGI = 2, CBI = 3

Students Id #	Groups	Proporti-onal Rea.	Control Var.	Probabili-stic Rea.	Correlati-onal Rea.	Combinat-orial Rea.	Total
1	2	2	2	2	2	0	8
2	2	2	1	0	1	0	6
3	3	2	2	2	2	1	9
4	1	0	2	1	0	0	3
5	1	1	1	0	0	0	2
6	3	0	2	1	0	1	4
7	3	2	2	2	2	2	10
8	3	2	2	2	2	2	10
9	3	2	1	0	2	0	5
10	1	2	1	1	0	0	4
11	2	2	2	2	1	2	9
12	2	0	1	1	2	0	4
13	2	1	2	2	1	0	6
13	2	1	2	2	1	0	6
14	2	2	2	2	1	0	7
15	2	2	2	1	0	0	5
16	1	2	1	1	0	0	4
17	2	2	2	2	2	0	8
18	2	2	1	2	2	1	8
19	3	2	2	2	2	1	9
20	1	2	1	2	0	0	5
21	1	1	1	1	0	0	3
22	3	2	2	2	0	0	6
23	1	0	2	1	1	0	4
24	1	2	2	2	0	1	7
25	3	1	0	1	1	0	3
26	1	2	2	2	1	2	9
27	1	2	2	0	1	0	5
28	3	2	1	0	0	0	3
29	2	1	1	2	0	0	4
30	1	2	2	2	1	0	7
31	3	1	1	0	0	0	2
32	2	2	2	1	1	0	6
33	2	2	2	1	0	0	5
34	1	2	2	0	0	0	4
35	3	2	2	0	1	0	5
36	1	1	1	0	1	0	3
37	3	1	1	0	0	0	2
38	2	2	1	1	0	0	4
39	1	2	2	1	0	0	5

40	1	2	2	2	2	1	9
41	1	2	1	1	1	0	5
42	3	2	2	2	2	0	8
43	2	2	1	1	0	0	4
44	3	2	1	1	1	0	5
45	3	2	2	2	1	0	7
46	1	2	2	2	2	2	10
47	2	2	2	2	2	2	10
48	2	2	1	1	1	0	5
49	1	2	2	0	0	0	4
50	1	1	1	1	0	0	3
51	3	2	2	2	1	0	7
52	1	2	2	2	2	0	8
53	2	2	2	2	2	2	10
54	3	2	0	1	1	0	4
55	1	2	1	1	1	0	5
56	1	2	2	2	1	2	9
57	2	1	2	1	2	1	7
58	1	2	1	1	1	0	5
59	1	1	1	2	0	0	4
60	3	1	1	1	0	0	3
61	1	2	1	1	0	0	4
62	3	2	2	2	2	0	8
63	3	2	2	2	2	1	9
64	2	2	1	2	2	0	7
65	3	2	2	2	2	0	8
66	3	2	1	1	1	0	5
67	3	2	2	2	2	2	10
68	1	2	2	2	2	2	10
69	3	2	2	2	1	0	7
70	2	1	1	2	0	0	4
71	2	1	2	1	1	0	5
72	2	2	2	2	2	0	8
73	1	2	2	2	2	1	9
74	2	1	1	1	0	0	3
75	2	1	1	0	0	0	2
76	2	2	2	0	0	0	4
77	1	1	2	1	1	0	5
78	3	2	2	1	1	0	6
79	1	2	2	1	2	0	7
80	3	2	2	2	0	0	6
81	1	2	2	2	2	0	8

82	2	1	2	2	2	0	7
83	3	2	2	2	2	0	8
84	3	2	2	2	2	2	10
85	3	1	2	1	1	0	5
86	2	2	2	2	2	0	8
87	1	2	2	2	2	1	9
88	2	1	1	1	1	0	4
89	2	2	2	2	1	0	7
90	2	1	1	1	0	0	3

Appendix I

Individual students' FCI scores

Treatments:

CTI = 1, CTGI = 2, CBI = 3

Student Id#	Groups	Gender	Pass / No	Q1	Q2	Q3	Q4
10	1	1	0	3	5	3	5
16	1	0	0	3	5	3	5
20	1	0	1	3	5	4	5
26	1	1	0	3	5	3	5
4	1	0	0	3	5	3	5
21	1	0	1	3	5	3	5
5	1	0	0	3	5	2	4
23	1	0	0	3	1	4	4
27	1	0	0	2	1	4	4
30	1	0	0	3	5	3	5
41	1	0	0	3	5	1	5
40	1	0	1	3	5	3	5
34	1	0	0	3	5	3	4
36	1	1	0	5	5	4	5
39	1	0	0	3	5	3	5
50	1	0	0	1	1	3	5
46	1	1	1	3	5	4	5
49	1	1	0	3	1	3	4
52	1	1	0	3	5	4	3
61	1	0	1	3	5	2	5
55	1	0	0	3	5	2	5
58	1	0	0	3	5	3	4
73	1	0	0	5	5	4	5
68	1	0	0	3	5	4	4
56	1	0	0	3	5	3	5
59	1	0	0	3	5	3	5
81	1	1	0	3	5	3	5
77	1	1	0	3	5	3	5
79	1	1	0	3	5	4	5
87	1	1	0	3	5	4	5
1	2	0	0	3	5	3	5
14	2	1	0	3	5	3	5
13	2	1	1	3	5	4	5
18	2	1	1	3	5	4	5
2	2	0	0	4	5	2	4
11	2	1	1	3	5	4	5
12	2	0	0	3	5	4	5
15	2	0	0	3	1	3	5
17	2	0	0	4	5	4	5

32	2	0	1	3	5	3	5
38	2	0	0	2	1	1	4
33	2	0	0	3	5	4	5
29	2	0	1	3	5	3	5
76	2	1	0	3	1	4	1
47	2	0	0	3	5	3	5
43	2	0	1	3	5	3	5
48	2	0	0	1	5	4	5
53	2	1	0	3	1	3	5
75	2	1	1	3	5	4	5
64	2	1	0	1	3	4	5
57	2	0	0	3	5	4	5
71	2	0	0	1	5	1	5
70	2	0	0	3	5	3	5
74	2	0	0	3	5	2	5
72	2	1	0	3	5	3	5
82	2	1	1	3	3	4	5
90	2	1	0	3	5	4	5
86	2	0	0	3	5	3	5
89	2	1	1	3	1	4	5
88	2	1	0	3	5	4	5
7	3	1	0	3	5	3	4
8	3	1	0	3	1	2	5
19	3	1	1	3	5	4	5
24	3	1	1	3	5	4	5
25	3	0	0	4	5	2	5
22	3	1	1	3	5	4	5
3	3	0	1	3	5	4	5
9	3	1	1	3	5	4	5
6	3	0	1	3	5	4	5
37	3	0	1	3	5	3	5
35	3	0	1	3	5	4	5
31	3	0	0	1	1	3	4
28	3	0	1	3	5	4	5
42	3	1	1	3	5	4	5
51	3	1	0	4	1	3	5
45	3	1	1	3	5	4	5
44	3	1	1	3	5	4	5
54	3	1	1	3	5	3	4
60	3	0	1	3	5	3	5
67	3	1	1	3	5	4	5
69	3	0	1	3	5	3	5

66	3	0	1	3	5	3	5
62	3	1	1	3	5	4	5
63	3	1	1	3	5	3	5
65	3	0	0	3	3	2	5
85	3	1	1	3	5	3	5
80	3	1	1	3	5	2	5
83	3	0	1	3	5	3	5
84	3	1	1	3	5	4	5
78	3	1	1	3	5	4	5

Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
3	2	3	4	1	4	4	5
3	2	3	3	1	3	3	5
2	2	3	1	1	3	5	4
2	2	3	3	0	4	3	5
2	3	3	1	0	4	3	5
2	2	3	3	1	3	5	2
2	3	2	3	1	4	3	5
2	3	3	3	0	4	3	1
3	4	3	4	1	4	2	1
3	2	3	3	0	4	3	3
2	3	2	3	1	4	3	5
2	2	3	3	1	3	5	4
2	3	3	2	0	4	3	5
2	2	3	1	1	3	4	5
2	2	5	3	1	3	3	5
2	2	3	3	1	4	1	1
2	2	3	4	1	3	5	2
2	3	2	2	1	3	3	1
2	2	3	1	0	4	3	5
2	2	3	5	1	3	5	4
2	3	2	4	1	4	4	5
2	2	2	1	1	4	3	5
2	2	3	4	1	1	4	3
2	3	3	3	0	3	4	3
3	2	3	3	0	4	2	5
2	3	3	2	1	4	1	5
2	2	3	2	0	3	4	3
2	3	3	1	1	4	3	1
2	3	3	1	1	4	4	3
2	1	3	4	0	2	2	3
2	2	3	5	1	4	3	5
2	3	3	2	0	3	4	1
3	2	5	4	1	3	5	2
2	2	3	2	1	4	5	4
2	3	2	3	1	4	4	5
2	2	3	4	0	3	5	3
2	4	5	4	0	4	3	5
2	3	3	3	0	3	5	1
2	3	2	3	0	3	4	5
2	2	3	1	1	3	5	4

2	2	3	4	0	4	2	1
2	4	2	1	0	4	3	5
2	2	3	3	1	3	5	2
2	3	3	1	1	3	3	1
2	2	3	1	1	1	3	5
2	2	3	4	1	4	5	4
2	3	3	1	0	4	1	5
2	3	3	3	1	3	3	2
2	2	3	4	0	4	5	5
2	2	3	1	0	4	1	3
2	2	3	1	1	4	4	3
2	3	3	3	0	3	1	5
2	2	3	3	0	4	3	4
2	3	2	3	0	1	4	3
2	2	3	1	0	1	2	5
2	2	3	1	1	3	5	3
2	3	3	3	1	1	3	1
2	2	3	3	1	4	2	1
2	2	3	4	0	3	5	4
2	1	3	1	0	3	2	3
2	2	3	3	0	5	1	5
2	3	3	3	1	1	4	1
2	2	3	4	1	3	5	4
2	2	3	4	1	3	5	2
2	2	2	4	0	4	4	5
2	2	3	4	1	3	5	2
2	2	4	2	1	3	5	4
2	3	3	4	1	3	5	2
2	2	3	4	1	1	5	4
2	2	3	3	0	3	5	2
2	3	3	4	0	4	4	2
2	3	1	2	1	3	1	4
2	2	3	1	1	3	5	5
2	2	3	4	1	3	3	2
2	2	3	5	0	4	4	1
2	2	3	3	1	4	5	5
2	2	1	2	0	3	5	4
2	2	5	4	1	3	5	2
2	2	3	4	1	2	5	4
3	2	3	4	1	4	4	4
2	2	3	2	1	3	5	2
2	2	3	4	1	3	5	4

3	2	3	4	1	3	5	2
2	2	3	4	1	3	4	4
2	3	1	4	0	4	3	3
2	2	3	3	1	3	5	2
2	2	3	1	1	3	5	3
2	2	3	4	1	1	5	4
2	2	3	4	1	4	4	4
2	2	3	4	1	3	5	4

Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
3	5	1	3	3	5	3	5
1	1	2	2	3	2	2	5
2	4	2	3	1	3	3	4
4	4	2	3	3	3	3	1
4	4	5	4	3	4	3	4
3	5	3	4	2	3	3	4
2	5	2	3	2	4	3	5
1	5	3	2	3	2	2	5
3	4	2	3	4	2	1	3
4	5	2	2	4	1	5	4
3	5	5	2	3	2	3	5
3	5	2	2	3	3	1	1
1	5	3	2	3	2	2	5
3	4	2	3	2	2	3	5
4	3	4	4	3	1	3	5
1	1	2	2	3	2	3	5
2	5	2	3	2	4	3	5
3	4	2	2	2	1	3	4
4	5	3	1	3	4	5	5
4	2	2	3	1	3	3	4
3	5	5	2	3	3	3	3
2	4	1	1	3	2	3	5
3	5	2	2	5	4	3	5
3	5	2	3	3	1	4	1
4	2	2	3	4	1	3	5
4	5	2	1	3	4	3	4
1	2	2	2	3	5	3	2
3	3	4	3	3	2	1	4
1	1	3	2	5	4	2	5
1	1	3	2	3	3	2	5
2	4	2	3	3	2	4	5
1	1	3	2	3	4	3	5
4	1	2	2	5	4	3	5
3	5	2	3	3	3	3	1
4	3	2	3	2	2	4	5
1	1	2	2	3	1	3	5
5	4	2	4	5	4	2	1
1	5	2	4	3	1	2	2
1	5	3	2	3	2	1	5
4	1	2	3	3	1	3	1

3	1	3	2	3	1	3	5
1	1	2	2	3	2	2	5
4	5	2	3	3	1	1	5
3	5	2	3	3	3	3	1
1	1	3	2	3	2	2	5
4	5	2	2	3	1	1	3
4	5	2	2	3	1	3	5
1	5	2	3	5	3	1	5
3	5	2	2	3	3	5	4
2	5	2	3	2	2	3	5
3	1	3	2	5	1	3	4
1	5	3	2	3	2	3	5
4	5	2	3	4	2	3	5
3	1	2	4	1	2	2	4
1	5	3	2	3	4	3	5
1	5	2	1	1	2	2	5
3	4	3	2	3	3	3	5
2	1	2	3	3	2	4	5
1	1	3	2	3	2	3	5
1	2	3	2	3	2	5	5
2	5	2	2	3	4	4	5
1	1	3	2	3	2	3	5
1	1	3	2	3	2	2	5
1	1	3	2	3	4	3	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	3	5
3	4	2	3	3	2	1	1
1	1	3	2	3	2	2	5
1	1	3	2	3	2	3	5
3	1	2	2	3	5	4	1
1	1	3	2	3	2	3	5
1	1	3	2	3	2	2	5
1	1	3	2	5	4	2	5
1	1	3	2	3	4	2	5
1	1	3	2	3	2	3	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	3	5
1	1	3	2	3	2	3	5
2	1	2	3	1	4	3	3
1	1	3	2	3	2	2	5

1	1	3	2	3	2	2	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	2	5
4	3	3	2	3	2	2	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	2	5
1	1	3	2	3	2	2	5
4	3	3	2	3	2	2	5

Q21	Q22	Q23	Q24	Q25	Q26	Q27	Scores
3	2	3	5	3	4	3	12
3	4	3	3	4	3	2	10
4	5	4	5	2	2	1	20
3	5	3	4	4	3	3	11
3	5	2	3	3	1	3	9
4	4	4	2	2	2	1	22
2	3	2	3	2	4	3	9
4	3	2	3	3	3	3	7
1	2	3	4	3	4	2	10
3	5	3	1	3	3	5	13
1	5	2	3	2	3	2	8
4	4	4	2	2	2	1	16
3	4	2	3	3	4	3	10
3	5	2	2	3	1	5	11
3	5	2	2	5	3	3	9
3	4	2	2	3	3	1	5
4	5	4	5	2	4	1	21
3	4	2	3	2	1	3	10
4	3	2	2	3	1	3	8
4	5	4	5	2	2	1	19
2	5	2	3	2	4	3	6
3	4	2	2	2	1	5	12
4	5	2	2	3	4	4	13
3	2	2	3	3	3	5	11
3	5	3	2	1	3	2	10
3	5	2	3	3	2	4	13
3	5	2	2	3	2	2	12
3	3	3	4	1	1	5	10
5	5	1	3	4	1	2	13
4	5	2	1	3	4	4	12
3	3	5	2	3	5	2	13
4	4	5	4	3	3	5	11
4	5	4	5	2	2	1	23
3	4	4	5	2	2	1	21
2	5	2	1	3	1	4	11
4	4	4	5	2	2	1	24
4	5	2	4	5	4	2	12
1	5	2	5	3	3	3	13
2	1	5	3	5	3	4	10
4	5	4	5	2	1	1	21
4	4	2	2	3	4	2	12

4	5	2	4	2	1	4	9
4	4	4	5	2	2	1	19
4	1	2	4	3	1	5	10
3	5	2	2	3	1	3	8
4	4	2	5	2	2	1	18
4	1	2	3	3	1	2	11
3	5	2	3	3	2	1	12
4	4	2	5	3	4	1	22
4	5	2	2	3	1	5	9
1	5	2	5	3	2	4	12
4	2	2	3	3	5	1	10
3	5	4	2	1	3	5	8
2	3	4	3	4	3	2	6
3	5	2	2	3	1	4	11
4	4	4	5	2	1	1	23
4	5	2	3	3	2	5	11
3	4	3	2	3	3	1	12
4	4	4	5	2	2	1	25
4	5	2	1	2	1	3	12
3	4	2	2	2	3	5	12
2	5	2	3	2	5	4	10
4	4	5	5	3	2	1	17
4	4	4	2	2	2	5	16
2	5	2	2	2	4	1	10
4	5	4	2	2	2	1	19
4	4	2	4	2	2	1	20
4	4	2	5	2	2	3	22
4	5	4	5	3	4	1	23
3	4	4	5	2	3	1	16
4	4	5	3	3	2	1	19
4	4	2	3	1	4	5	10
4	4	4	2	2	2	3	21
4	5	4	5	2	4	1	18
4	5	2	2	3	5	4	5
4	4	4	5	2	2	1	17
4	4	2	2	2	2	1	19
4	4	4	3	2	2	1	21
3	4	4	5	3	4	1	16
4	4	4	2	2	2	3	18
3	4	4	5	3	2	1	20
4	5	4	5	3	2	1	15
4	5	4	5	2	2	1	19

4	4	2	5	2	2	1	17
2	4	2	3	1	2	3	13
3	4	4	5	2	2	1	15
4	4	4	2	2	1	1	17
4	4	2	2	2	2	1	22
4	4	4	5	3	2	1	19
4	4	4	5	2	2	3	21

Appendix J

All Individual students' TOLT scores

Treatments:

CTI = 1, CTGI = 2, CBI = 3

Students ID #	Q1	R1	Q2	R2	Q3	R3	Q4
10	3	1	2	1	3	5	1
16	3	1	2	1	5	5	5
20	3	1	2	1	3	5	1
26	1	1	4	2	4	1	2
4	3	1	2	1	3	5	1
21	3	1	2	1	3	5	1
5	3	1	2	1	5	2	5
23	3	1	2	1	3	5	1
27	3	1	2	1	3	5	1
30	3	1	3	1	3	5	1
41	3	1	2	1	5	2	1
40	3	1	2	1	3	5	1
34	3	1	2	1	3	5	1
36	3	1	2	1	3	5	1
39	3	1	2	1	3	5	1
50	3	1	2	1	3	5	1
46	3	1	2	1	3	5	1
49	3	1	2	1	5	2	5
52	3	1	2	1	3	5	2
61	3	1	2	1	3	5	1
55	3	1	2	1	3	5	1
58	3	1	2	1	3	5	1
73	3	1	2	1	3	5	1
68	3	1	2	1	3	5	1
56	3	1	2	1	3	5	1
59	3	1	2	1	3	5	1
81	3	1	2	1	3	5	1
77	3	1	2	1	5	2	1
79	4	4	3	2	3	5	1
87	3	1	3	1	3	5	1
1	3	1	2	1	3	5	1
14	2	1	2	1	3	4	1
13	1	1	4	1	3	5	1
18	3	1	5	1	5	2	4
2	2	1	2	1	3	5	1
11	3	1	5	5	3	5	5
12	3	1	2	1	5	2	1
15	1	4	2	1	3	4	1
17	3	4	2	1	3	5	1
32	3	1	2	1	3	5	1

38	3	1	2	5	3	5	1
33	3	1	2	1	3	5	1
29	3	1	2	1	3	5	1
76	3	1	2	1	3	5	1
47	3	2	2	3	5	1	2
43	3	1	2	1	3	5	1
48	3	1	2	1	3	5	1
53	3	1	2	1	4	1	2
75	3	1	2	1	3	5	1
64	3	1	2	1	3	5	1
57	1	3	1	3	5	1	4
71	3	1	2	1	5	5	1
70	3	1	2	1	3	5	1
74	3	1	2	1	3	5	1
72	3	1	2	1	3	5	1
82	3	1	2	1	5	2	5
90	3	1	2	1	3	5	1
86	4	1	3	1	3	5	1
89	3	1	2	1	3	5	1
88	3	4	2	1	3	5	1
7	3	1	2	1	3	3	1
8	2	4	5	2	4	1	5
19	3	1	2	1	3	5	1
24	3	1	2	1	3	5	1
25	3	1	2	1	3	5	1
22	2	5	3	2	4	1	2
3	3	1	2	1	3	5	5
9	2	4	4	3	3	5	1
6	3	1	2	1	5	5	5
37	3	1	3	1	3	5	1
35	3	1	5	2	5	2	5
31	3	1	3	1	3	5	1
28	1	4	3	3	4	1	1
42	3	1	2	1	3	5	4
51	3	1	2	1	3	5	1
45	3	1	2	1	3	5	1
44	3	1	2	1	5	2	1
54	3	1	2	1	4	1	1
60	3	1	3	1	4	5	1
67	3	1	2	1	3	5	1
69	3	1	2	1	3	5	1
66	3	1	2	1	3	5	1

62	3	1	2	1	3	5	1
63	3	1	2	1	3	5	1
65	3	4	2	1	3	5	1
85	3	1	2	1	3	5	1
80	3	1	2	1	3	5	1
83	3	1	2	1	3	5	1
84	3	1	2	1	3	5	1
78	5	5	5	5	3	5	1

R4	Q5	R5	Q6	R6	Q7	R7	Q8
4	1	4	5	5	1	1	2
4	1	4	5	5	1	4	2
4	4	5	3	5	1	1	2
1	1	4	5	5	1	2	2
4	1	4	5	1	1	1	2
1	1	4	5	5	1	1	1
2	1	4	5	5	1	3	2
4	1	4	5	5	2	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	2	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	2	5	1	1	2
4	1	4	5	5	1	1	2
4	1	2	3	3	1	1	2
4	1	4	5	5	1	1	2
4	5	5	5	5	1	3	2
2	1	4	5	5	2	3	2
1	4	2	4	4	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	2	3
4	4	2	5	5	1	3	1
4	1	2	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	3	1
4	1	4	5	3	1	3	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	1
4	1	4	5	5	1	2	3
4	1	4	5	5	1	1	2
4	1	4	3	3	2	4	2
4	1	4	5	5	1	1	1
2	1	4	2	3	1	2	1
4	1	4	5	5	1	1	2
4	1	2	3	4	5	1	2
4	1	4	5	5	2	1	2
4	1	4	5	5	2	1	2
4	1	4	5	5	2	1	2

4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
1	4	2	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
1	4	2	4	1	1	1	2
4	1	4	5	5	2	1	2
4	1	4	5	5	2	1	2
2	2	4	5	5	1	1	1
4	1	4	5	5	1	1	2
4	1	4	5	5	1	3	2
4	1	4	5	5	1	1	2
4	1	1	3	2	4	2	4
1	1	4	1	5	2	1	2
4	1	4	5	5	1	1	2
4	4	4	4	4	3	2	4
4	1	4	5	3	1	2	2
4	1	4	5	5	1	1	2
1	4	2	3	5	2	1	2
2	2	3	3	3	2	4	2
4	1	4	5	5	2	1	2
4	1	4	3	5	1	2	2
4	1	4	5	5	1	4	2
1	2	3	4	1	1	1	2
4	1	4	2	5	2	1	1
4	1	4	5	5	1	1	2
4	1	4	5	5	2	1	2
4	1	4	5	5	2	1	2
2	1	4	5	5	1	3	2
4	1	4	5	5	1	1	2
4	2	3	3	1	2	4	2
1	1	4	5	5	1	1	2
4	2	4	3	5	11	1	2
4	1	4	5	5	1	1	2
4	5	4	5	5	2	2	2
4	2	3	5	5	1	1	2
4	1	5	1	4	2	4	2
4	1	4	5	5	1	1	2
4	2	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2

4	1	4	5	5	1	1	2
4	2	3	3	3	1	4	2
4	2	3	3	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	5	5	1	1	2
4	1	4	1	5	1	1	2

R8	Q9	Q10	Co/Formal	Gender	Groups	Scores
4	0	0	1	0	1	7
4	0	0	0	0	1	3
2	0	0	0	0	1	4
1	0	0	0	0	1	4
4	1	1	1	1	1	9
4	0	0	0	0	1	5
2	0	0	0	0	1	3
4	1	0	1	0	1	9
4	0	0	1	1	1	8
4	1	0	1	1	1	9
4	0	0	0	0	2	4
2	0	0	0	0	2	6
4	1	0	1	1	2	8
4	1	1	1	0	2	9
4	0	0	1	0	2	8
4	0	0	1	1	2	7
4	0	0	0	0	2	4
1	0	0	0	1	2	2
4	0	0	0	0	2	5
2	1	1	1	1	3	10
4	0	0	1	1	2	8
4	1	1	1	0	2	8
4	0	0	0	0	3	3
4	0	0	0	1	3	5
4	0	0	1	1	2	7
4	0	0	1	1	2	7
4	0	0	1	1	3	7
4	0	0	0	1	3	5
4	0	0	0	0	3	3
4	0	0	1	1	3	6
4	0	0	0	1	1	4
4	0	0	0	1	1	3
4	0	0	0	0	1	4
1	0	0	0	1	1	4
4	0	0	0	0	1	4
2	0	0	0	0	1	5
4	1	0	1	0	1	9
3	0	0	0	0	1	5
4	1	1	1	1	1	10
4	0	0	1	1	2	7
4	0	0	0	0	2	5

4	0	0	1	1	2	6
4	0	0	1	1	1	7
4	0	0	1	1	3	7
5	0	0	0	0	2	5
2	0	0	0	0	2	4
4	1	1	1	1	2	10
4	0	0	0	0	2	4
4	0	0	1	1	3	7
4	1	0	1	1	1	7
4	0	0	0	1	2	3
4	0	0	0	0	3	5
2	0	0	0	0	3	2
4	0	0	1	1	3	8
4	0	0	0	0	3	2
4	0	0	0	1	3	5
4	0	0	1	1	3	6
3	1	0	0	1	3	5
4	1	1	1	1	3	10
4	0	0	1	0	3	8
4	0	0	0	0	1	2
5	0	0	0	0	1	4
4	0	0	1	1	1	8
4	1	1	1	0	1	10
4	1	1	1	0	1	9
2	0	0	0	0	1	5
2	0	0	0	0	1	5
4	0	0	0	0	1	5
4	0	0	0	0	1	3
4	0	0	0	0	2	4
3	0	0	0	0	2	4
4	0	0	1	0	2	8
3	0	0	0	1	1	5
3	0	0	0	0	2	5
4	1	0	1	0	2	7
4	1	1	1	0	2	10
5	0	0	0	1	2	4
4	0	0	0	0	2	3
1	0	0	0	1	2	4
4	1	0	1	0	3	9
3	1	0	0	0	3	4
4	0	0	1	1	3	6
4	1	1	1	1	3	10

4	1	0	1	1	3	9
4	0	0	0	0	3	3
4	0	0	1	0	3	8
4	1	1	1	0	3	10
4	0	0	1	1	3	8
4	1	0	1	1	3	9
4	0	0	0	1	3	4

Appendix K

Individual students' LAQ scores

Rote Learner = 0

Meaningful Learner = 1

Students Age	Ethnic	M/High	F/High	Grade/H	Grade/S	Grade/R	Grade/T
19	2	2	1	4	4	4	4
19	2	2	2	4	4	4	4
19	2	4	4	4	4	4	4
20	0	3	2	3	4	4	4
19	1	4	4	4	4	4	4
18	2	3	3	4	4	4	4
20	2	2	4	3	3	3	3
22	2	4	2	4	3	4	4
20	5	2	4	3	3	3	3
20	2	3	1	4	4	3	3
24	4	1	2	4	4	3	3
24	2	2	2	3	3	4	4
26	2	1	1	3	4	2	3
19	2	1	1	4	3	3	4
19	1	3	2	4	3	3	3
20	2	4	3	4	3	4	4
20	1	2	0	3	3	3	3
25	5	2	3	3	4	3	3
19	2	3	4	4	4	4	4
20	2	2	2	4	4	3	3
26	2	4	3	4	4	4	4
19	2	1	4	3	4	4	3
28	2	0	1	3	3	4	3
21	2	4	4	4	4	4	4
19	1	3	3	4	4	4	4
19	4	2	1	4	3	3	4
25	2	3	2	3	4	4	4
20	2	3	4	4	3	4	4
19	2	3	4	4	3	4	4
21	2	3	0	4	4	4	4
18	1	3	4	4	3	3	1
19	2	2	1	4	4	4	4
19	2	2	2	4	4	3	4
20	2	4	2	4	4	4	3
19	2	2	2	4	4	4	4
23	2	1	4	3	4	3	4
22	2	2	2	3	3	3	4
19	4	4	4	4	3	3	3
20	0	2	2	4	4	4	4
20	2	4	4	4	4	3	3

20	4	1	2	4	3	3	2
21	2	3	2	4	4	4	4
23	2	1	4	4	3	4	3
20	2	3	2	4	4	3	2
26	2	0	0	3	3	3	3
22	2	3	1	4	4	4	4
22	2	4	4	4	3	4	3
21	5	2	0	3	3	4	4
21	5	2	0	3	3	4	4
20	2	2	3	4	3	4	3
20	1	1	1	4	3	3	3
20	2	0	2	4	4	3	3
21	2	2	3	4	3	4	3
19	1	3	4	4	4	4	3
34	3	0	1	3	3	4	3
22	4	2	1	3	4	4	4
22	2	1	1	4	4	4	4
20	2	1	1	4	3	3	3
20	2	4	3	3	3	2	3
20	2	2	4	4	3	3	3
20	2	2	4	3	3	3	3
22	2	4	2	4	3	4	4
20	2	2	4	4	4	4	4
20	2	1	3	4	4	4	4
20	4	4	4	3	3	3	3
21	5	3	1	2	3	3	3
19	2	4	4	4	4	4	4
20	5	2	4	3	3	3	3
18	2	3	3	4	4	4	4
19	2	1	2	4	3	4	3
20	5	1	3	4	4	4	4
19	2	3	4	4	4	3	4
22	2	3	3	4	4	4	3
20	2	3	3	3	4	4	3
19	2	2	0	4	3	4	4
19	2	2	2	3	3	4	3
19	4	3	3	4	4	4	3
25	2	3	4	4	4	4	4
20	2	2	3	4	4	4	4
19	1	3	4	4	4	4	4
19	3	3	4	4	3	4	4
20	2	4	4	4	4	4	3

20	2	2	2	4	4	3	3
19	3	3	4	4	3	4	4
20	2	4	4	4	4	4	3
20	2	3	3	4	3	4	4
20	2	3	3	4	3	4	4
23	2	3	3	4	3	4	4
19	0	1	1	4	3	3	3
20	1	4	4	4	4	4	4

Grade/U	M1	R1	M2	R2	R3	M3	R4
1	2	2	2	1	3	3	2
1	1	2	2	2	2	2	4
1	1	2	2	4	4	2	4
1	2	4	3	3	2	2	5
1	1	2	1	4	3	2	3
1	1	1	2	2	3	2	3
1	2	2	2	2	2	2	2
3	1	4	1	4	4	2	5
2	2	3	3	5	2	1	4
1	2	1	2	1	2	1	1
1	2	3	2	3	4	2	2
1	1	3	2	4	4	1	4
1	2	3	2	3	2	2	3
1	2	1	3	1	2	1	1
1	2	1	3	2	1	1	2
1	2	4	3	4	3	2	4
1	1	1	1	1	1	2	4
1	2	3	2	1	2	2	1
1	2	4	3	3	3	2	5
1	2	2	3	1	3	1	2
3	1	3	1	4	4	1	5
1	2	1	3	1	3	2	1
1	2	1	2	3	1	1	2
1	1	2	3	2	4	2	5
1	2	4	2	4	3	1	4
1	1	1	5	3	4	2	5
4	1	3	3	2	1	3	2
1	2	2	3	2	3	2	3
1	1	2	2	4	2	2	4
1	3	3	4	4	3	3	2
1	2	2	2	1	3	3	2
1	2	1	4	4	4	2	2
1	3	2	3	2	2	3	2
2	2	2	2	3	2	1	2
1	1	2	2	2	2	2	4
1	1	4	2	4	4	1	1
1	2	1	1	1	3	2	2
1	2	2	3	2	1	2	1
1	1	2	3	1	4	2	4
1	2	3	1	2	4	2	4
1	2	3	3	2	3	3	3

1	2	3	1	5	4	3	3
2	1	1	1	1	1	1	3
1	2	3	2	3	3	1	3
1	2	3	2	1	1	1	4
1	2	3	2	2	3	1	2
1	1	2	2	2	4	3	4
1	2	1	3	3	1	1	3
1	2	1	3	3	1	1	3
1	2	2	2	1	2	2	2
1	3	2	4	3	2	2	3
1	3	3	3	2	4	3	3
1	2	3	3	2	2	2	4
1	2	3	2	4	3	3	3
1	1	3	2	2	2	2	3
1	2	3	1	3	3	1	3
1	2	3	2	3	4	2	4
2	3	1	3	2	2	2	2
1	2	2	3	5	2	1	1
1	1	2	1	1	2	2	1
1	2	2	2	2	2	2	2
3	1	4	1	4	4	2	5
1	2	4	2	3	4	2	4
1	2	2	3	2	2	2	3
1	2	2	3	4	2	1	2
2	3	2	3	2	2	3	3
1	1	2	2	4	4	2	4
2	2	3	3	5	2	1	4
1	1	1	2	2	3	2	3
1	3	1	5	1	3	3	1
1	1	1	2	1	1	1	3
1	1	1	1	1	4	1	5
1	1	2	4	3	4	1	2
2	2	2	4	2	3	1	2
1	2	3	2	3	3	1	4
2	2	3	1	2	2	4	2
1	3	2	2	2	3	3	2
1	1	3	4	3	4	1	4
1	1	2	2	4	4	4	4
1	2	2	3	1	2	2	4
1	1	2	3	2	3	2	4
1	1	2	3	2	3	2	1
1	1	2	1	3	3	1	3

1	1	2	3	2	3	2	4
1	1	2	3	2	3	2	1
1	2	3	2	3	4	2	3
1	1	2	1	4	3	2	3
1	2	1	4	3	5	2	2
1	1	3	2	4	4	3	2
1	2	2	2	4	3	2	2

M4	M5	M6	M7	M8	M9	R5	R6
4	4	3	2	2	2	3	3
3	3	3	3	2	1	2	3
2	2	1	5	3	2	4	2
3	2	3	2	2	4	3	2
2	3	2	3	2	1	2	2
4	2	2	1	2	1	3	2
3	2	3	2	2	2	2	2
1	1	1	1	2	1	3	5
4	3	3	1	2	2	4	3
3	3	2	1	2	3	2	2
3	4	4	3	3	2	3	3
4	1	2	2	1	1	3	3
3	2	3	2	2	2	2	2
3	3	3	2	2	1	2	2
2	3	3	2	2	3	2	1
3	1	3	4	2	2	4	3
2	2	1	1	3	1	3	1
3	4	4	2	2	4	3	2
2	3	3	3	1	2	3	2
2	2	2	1	1	1	3	2
2	1	2	1	1	1	4	5
4	4	2	4	2	2	3	2
5	3	4	2	2	3	3	3
3	2	2	2	1	2	3	2
2	2	3	2	2	2	4	4
3	1	1	1	1	2	4	3
3	3	4	2	3	2	1	3
2	3	4	4	2	2	3	3
1	1	4	3	2	1	5	2
4	3	2	3	3	1	3	4
4	4	3	2	2	2	3	3
4	4	2	3	3	2	2	2
3	3	3	3	2	2	3	2
4	3	4	2	2	4	4	3
3	3	3	2	1	2	2	3
3	4	1	1	1	1	3	2
4	3	2	1	4	2	2	2
3	4	3	1	2	3	3	1
5	1	5	3	1	2	3	1
2	1	3	2	2	1	3	4
3	4	3	2	3	3	3	2

2	1	1	2	2	1	4	3
3	3	4	2	2	2	3	4
2	3	2	2	3	2	4	2
2	2	2	2	2	1	3	3
2	2	3	1	2	1	3	2
5	3	2	2	2	1	4	3
3	1	4	2	1	2	3	2
3	1	4	2	1	2	3	2
3	2	2	2	2	2	4	2
2	4	4	3	4	4	2	2
3	2	3	3	3	2	4	4
4	2	1	2	3	2	3	3
2	2	1	3	3	2	3	4
2	3	2	2	3	2	4	3
2	2	2	1	3	1	2	2
3	2	4	2	3	2	3	4
3	3	3	2	3	3	3	3
5	5	3	1	1	1	1	1
2	3	4	2	3	3	2	2
3	2	3	2	2	2	2	2
1	1	1	1	2	1	3	5
2	2	2	3	2	2	2	3
3	1	2	2	1	1	3	1
3	1	3	2	2	2	3	3
3	4	2	3	2	4	2	2
2	1	5	3	2	2	4	2
4	3	3	1	2	2	4	3
4	2	2	1	2	1	3	2
4	4	5	3	3	5	1	1
3	2	1	2	1	1	3	2
1	1	3	1	1	1	3	5
2	2	4	1	2	2	4	3
3	4	5	4	2	5	2	2
2	2	1	1	1	1	3	3
3	2	3	2	2	2	3	2
4	3	2	3	4	2	2	3
3	3	3	1	1	1	4	4
4	3	3	2	1	1	2	3
3	2	4	2	2	3	2	3
3	4	1	2	3	1	2	3
2	3	4	1	2	2	1	1
4	2	4	2	1	1	3	3

3	4	1	2	3	1	2	3
2	3	4	1	2	2	1	1
3	2	2	1	1	3	2	3
2	3	4	1	2	1	5	1
1	3	4	2	2	3	1	3
3	4	3	3	3	2	2	4
3	3	2	1	1	2	2	1

R7	R8	M10	R9	M11	M/R	St. ID #	Scores
4	2	4	3	2	0	10	8
4	2	2	3	3	1	16	12
4	4	2	5	3	1	20	13
2	1	2	2	3	1	26	10
3	1	2	2	1	1	4	11
5	2	4	4	2	1	21	12
2	3	2	3	3	1	5	11
5	2	1	5	1	1	23	14
4	3	5	4	2	1	27	13
3	3	2	1	2	1	30	14
4	4	3	4	2	1	41	15
5	2	3	2	1	0	40	7
4	3	3	4	2	0	34	8
3	1	3	2	3	0	36	8
3	1	3	2	2	0	39	9
4	5	4	3	2	1	50	11
5	1	1	2	1	1	46	12
4	3	3	4	2	0	49	8
4	3	3	4	2	1	52	13
4	2	2	4	2	1	61	15
5	2	1	5	1	1	55	12
5	1	5	4	3	0	58	8
4	1	2	4	3	1	73	13
4	4	3	4	1	1	68	12
5	2	2	4	2	0	56	7
5	5	2	4	1	0	59	8
3	2	4	3	3	1	81	11
4	2	4	3	3	1	77	12
5	3	4	4	2	1	79	11
4	1	4	3	3	1	87	15
4	2	4	3	2	1	1	14
2	2	4	3	2	1	14	12
2	2	3	2	3	1	13	10
3	1	3	2	2	1	18	11
4	2	2	3	3	1	2	10
4	4	2	4	1	0	11	7
2	1	3	3	2	0	12	8
1	2	3	1	3	1	15	13
2	1	1	3	2	0	17	9
4	3	2	4	2	1	32	11
5	3	3	3	2	1	38	12

5	4	3	4	2	0	33	6
3	1	2	2	1	1	29	10
4	1	3	2	3	0	76	9
4	1	1	4	2	0	47	7
3	3	3	3	2	1	43	13
4	3	3	4	2	1	48	14
5	2	4	4	4	1	53	12
5	2	4	4	4	1	75	16
4	2	4	3	3	1	64	15
4	4	2	2	2	1	57	11
3	2	3	4	3	1	71	12
5	3	4	5	2	1	70	13
4	2	3	2	2	1	74	11
4	2	3	4	2	1	72	11
5	4	3	3	2	1	82	12
4	2	3	2	2	0	90	8
2	2	3	2	2	0	86	7
2	1	4	1	4	1	89	13
3	2	2	2	2	1	88	14
2	3	2	3	3	1	7	11
5	2	1	5	1	1	8	10
2	4	4	2	4	1	19	12
4	2	2	4	2	1	24	13
5	1	3	3	2	0	25	8
3	3	2	2	2	1	22	13
4	4	2	5	3	0	3	7
4	3	5	4	2	1	9	11
5	2	4	4	2	1	6	12
2	1	4	4	2	1	37	14
5	3	4	1	1	1	35	15
5	4	3	4	1	1	31	11
2	4	5	5	3	1	28	12
2	2	5	4	4	1	42	15
5	2	2	4	1	0	51	8
2	2	2	2	1	1	45	10
1	2	2	2	3	0	44	7
3	3	2	5	2	0	54	8
4	4	3	5	2	1	60	15
4	2	4	4	4	1	67	16
4	2	2	5	3	0	69	8
4	3	5	4	2	1	66	10
5	3	4	4	2	1	62	13

4	2	2	5	3	0	63	7
4	3	5	4	2	1	65	16
4	4	2	3	1	0	85	6
3	3	2	1	1	0	80	5
2	4	1	4	1	0	83	7
5	3	2	3	3	0	84	6
3	2	2	1	2	1	78	16

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989