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DIGITAL VIDEO, LEARNING STYLES, AND STUDENT UNDERSTANDING OF KINEMATICS GRAPHS

by

Teresa L. Hein

B.S., South Dakota State University, 1982
M.S., South Dakota State University, 1985

A DISSERTATION

submitted in partial fulfillment of the

requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1997

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ABSTRACT

Student ability to analyze and interpret motion graphs following laboratory instruction that utilized interactive digital video as well as traditional instructional techniques was investigated. Research presented suggested that digital video tools serve to motivate students and may be an effective mechanism to enhance student understanding of motion concepts.

Two laboratory exercises involving motion concepts were developed for this study. Students were divided into two instructional groups. The treatment group used digital video techniques and the control group used traditional techniques to perform the laboratory exercises. Student understanding of motion concepts were assessed, in part, using the Test of Understanding Graphs-Kinematics. Other assessment measures included student responses to a set of written graphical analysis questions and two post-lab activities.

Possible relationships between individual learning style preferences and student understanding of motion concepts were also addressed. Learning style preferences were assessed using the Productivity Environmental Preference Survey prior to the instructional treatments. Students were asked to comment in writing about their learning styles before and after they were given the learning style assessment. Student comments revealed that the results they received from Productivity Environmental Preference Survey accurately reflected their learning styles.

Results presented in this study showed that no significant relationship exists between students' learning style preferences and their ability to interpret motion graphs as measured by scores on the Test of Understanding Graphs-Kinematics. In addition, the results showed no significant difference between instructional treatment and mean scores on the Test of Understanding Graphs-Kinematics.

Analysis of writing activities revealed that students in the treatment group responded more effectively than students in the control group to graphical interpretation questions that closely paralleled the motions they had observed during the laboratory. However, students in both instructional groups displayed similar levels of difficulty when confronted with motions that deviated from what they had observed in the laboratory.

After controlling for differences in student ability levels using SAT scores and course grades, a significant difference in mean scores on the Test of Understanding Graphs-Kinematics was observed between males and females. Males and females as a separate population had similar mean SAT scores and course grades. A suggestion was made that the observed difference between males and females based on mean scores on the Test of Understanding Graphs-Kinematics could be due to a gender bias inherent in the instrument. A recommendation was made that future studies could address this observed gender difference.

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DEDICATION

This dissertation is dedicated to the memory of my beloved friend and brother, Paulos Mebrahtu. Paulos showed me the true meaning of unconditional friendship. He will forever remain in my heart.

CHAPTER ONE

INTRODUCTION

This study was designed to investigate the influence of multimedia techniques. particularly those involving interactive digital video. on students' cognitive development processes for learning physics. This study focused strictly on students' processing of information in kinematics in the areas of one- and two-dimensional motion. Particular attention was given to students' ability to construct and interpret motion graphs. This study also addressed the role(s) that student learning styles play in terms of processing and developing concepts, particularly those introduced using interactive digital video techniques. This chapter contains background information regarding the use of multimedia techniques in the physics classroom, a brief overview of previous studies in students' learning in kinematics as well as an introduction to learning styles and their assessment. The problem to be addressed in this study is then outlined followed by the research hypotheses and questions. the underlying assumptions. and the significance of the study to the field of physics education research. A summary is then presented.

Background to the Study

Since the early 1980s a considerable amount of research has been done in the area of students' learning of kinematics concepts in introductory physics classes and laboratories (Halloun & Hestenes. 1985; McDermott. 1991: McDermott. Rosenquist & van Zee. 1987: Rosenquist & McDermott. 1987; Thornton & Sokoloff. 1990; Trowbridge & McDermott. 1980; Van Heuvelen. 1991). Students' difficulty grasping these concepts even after taking the traditional introductory physics courses is well documented. The topics covered within a typical unit on kinematics in an introductory college physics course provide a rich base for continued research.

One reason that topics in kinematics have been so interesting to investigate is that when students enter the physics classroom they do not do so with a tabula rasa. Rather, students already possess some degree of connection and familiarity with ideas of motion before they receive formal instruction. Students come to possess this knowledge based on their own life experiences. The fact that some preconceptions are held by many students suggests that some of these life experiences are shared and others are unique. Furthermore, this knowledge, whether scientifically sound or not, contributes, in part, to the formulation of an individual's world view. One's world view helps him/her to understand the "how" and the "why" of the way things move as they do. Cobern (1991, p. 21) suggested that the real driving force behind the development of a world view is one's need to relate to the outside world. From childhood on, people interact with the world around them and through this interaction their world views are constructed. Students' views of motion prior to entering the physics classroom often consist of both scientifically sound as well as unsound conceptions.

Part of the excitement of conducting research on students' understanding of motion concepts is the teasing out of conceptions that are inconsistent with the accepted models held by physicists, and the enhancement of those conceptions that are consistent with the accepted models held by physicists. The teasing out of conceptions that are inconsistent with models held by physicists can best be achieved through the use of some type of instructional vehicle(s). Through studies such as this current project, instructional delivery strategies can be developed and enhanced to assist students as they struggle to understand motion concepts.

Over the past decade, physics education research has increasingly focused on the use of interactive multimedia techniques in the classroom and laboratory. These techniques include the use of interactive videodisc instruction (Brungardt & Zollman, 1995; Martorella, 1989; Zollman, 1997; Zollman & Fuller, 1994) as well as interactive digital video (Chaudhury & Zollman, 1994; Escalada & Zollman, in press; Escalada, Grabhorn & Zollman, 1996; Zollman, 1994).

Other physics education researchers have studied students' understanding of motion concepts using computer-based laboratory techniques (Laws, 1991a; Thornton & Sokoloff, 1990). Still others have studied students' understanding of motion concepts using various other video motion analysis software (Beichner, 1996; Brasell & Rowe, 1993; Grayson & McDermott, 1996). However, no studies have been conducted to date which formally assess students' learning styles and their connection to student learning of kinematics following instruction that makes use of interactive digital video techniques.

Wilson (1994) indicated "Over the years we have turned to audio, video, and now computers to make lectures more interesting and instructive" (p. 518). Interviews with students revealed that although students could recall, from memory, a demonstration they had previously seen, they could not display a thorough understanding of the physics associated with it. Thus, traditional demonstrations do not necessarily lead to understanding.

Important factors affect student motivation toward learning physics. Donald (1993) indicated that students enter the university with certain attitudes toward learning and that these attitudes are pervasive and play a large role in determining how well students achieve. Koballa and Crawley (1985) also supported this idea and further indicated that students' attitudes toward science are learned predispositions. These researchers suggested that if educators fail to plan and teach for affective issues, such as student attitude development, a science curriculum that fails to help students make sound decisions regarding science as it relates to their future needs may be the end result.

Tobias (1990) has been critical of introductory college science courses and has argued that typical classrooms are "... competitive, selective and intimidating, and designed to winnow out all but the 'top tier'... there is little attempt to create a sense of 'community' among average students of science" (p. 9). Hence, a traditional science classroom may present barriers that could inhibit learning for some students. The laboratory setting provides students an opportunity to work in groups. A group approach to learning often reduces feelings of competitiveness among students. The reduction of competitive feelings can lead to the creation of a learning environment that is not intimidating for students. Furthermore, a learning environment that is not intimidating or threatening can give students enhanced opportunities to learn.

Dalton (1986) noted that various forms of computer-assisted instruction have been shown to have positive effects in such areas as learner attitudes and self-esteem. In a study on the effects of peer interaction for a group of fifth- and sixth- grade students during computer-based mathematics instruction, Hooper (1992) concluded that students completed the instructional tasks more efficiently when they worked in a group environment. Various computer-assisted and multimedia technologies, when used within a laboratory setting, provide a natural environment in which students can work in groups. In terms of individual learning styles, some students will not always prefer to learn in a group environment. However, one result of computer-based group instruction for many students may be the development of more positive attitudes toward the learning task which may ultimately lead to increased learning gains.

Assessment of student learning styles offers an important vehicle by which to address, in part, the issues of student attitude and motivation. Learning style is a rather broad term which encompasses such aspects as the learning environment, along with emotional, sociological, physical and psychological factors. A significant number of research studies have shown that students instructed in a classroom environment where individual learning differences are acknowledged and accepted are more receptive and eager to learn new and difficult information (Brandt, 1990; Dunn & Bruno, 1985; Dunn,

Dunn & Freely, 1984; Hein, 1994; Lemmon, 1985; Perrin, 1990). Cronin and Cronin (1992) stressed, however, that there are serious shortcomings with most studies involving "soft skill" (e.g. humanities and social sciences) areas and interactive video instruction. Regarding these shortcomings, these researchers argued that variables such as user's prior knowledge, ability level, learning style, attitude toward the instructional delivery system, experience with technology, and motivation to learn are typically not controlled or measured in most empirical studies. Although most of the studies with interactive video methods have been in the "hard" areas (e.g. math and science), a need remains to assess student learning styles and how they could impact a student's ability to learn from these various interactive video techniques.

The classrooms of the 1990s and beyond are sure to be representative of the diversity present in our society. Furthermore, respecting the learner as an individual is essential. Dunn & Griggs (1990) concluded that we should not be teaching to particular cultural or ethnic groups; rather, we should be teaching to individuals' learning strengths. Ultimately this approach may lead to improved attitudes toward learning as well as to increased achievement.

Factors which influence student motivation to learn physics are also of interest. Recently, studies have been conducted which looked at students' interpretation of concepts after instruction that includes some form of "real time" data collection or observation. The term "real time" as used here refers to the ability to view a video clip depicting the motion of a real event. Research conducted by Brungardt & Zollman (1995) with high school physics students using videodisc instruction allowed students to simultaneously view the motion of an object along with the corresponding kinematics graph of its motion on a computer screen. These investigators were interested in determining whether this simultaneous viewing was a significant factor in students' learning. Students in their study were divided into two groups. The first group saw the kinematics graph on the computer screen simultaneously with the motion of the object from the videodisc. The second group of students experienced a time delay between when they saw the motion of the object and the corresponding graphs. Brungardt and Zollman concluded that although the real-time effect did not prove to be a critical factor in improving student learning of kinematics graphic skills, it did serve to enhance learner motivation. These researchers noted that caution must be used, however, in interpretation of their results due to the small sample size that was used in their study. Brungardt & Zollman did note that novelty effects were reduced, however, because the study was conducted over an extended treatment period.

Regarding novelty effects, Najjar (1996) cautioned that as students become more familiar with using various multimedia learning tools, the novelty will most likely wear off, and the learning advantages may decrease. He concluded that "... the novelty of multimedia information has a slight, temporary, positive effect on learning" (p. 132). Najjar also suggested that multimedia information also appears to be more effective for novice learners, possibly because experts already have a cognitive model to connect to while novices do not.

In addition to research on multimedia and its role in physics learning, studies have been conducted which look at the possible benefits of computer-based activities. One question to be addressed is, if students find these tools more palatable, are they actually learning better? Thornton and Sokoloff (1990) have maintained "There is strong evidence for significantly improved learning and retention by students who used the microcomputer-based laboratories materials, compared to those taught in lecture" (p. 862). These researchers discussed five main characteristics of the learning environment that are made possible by the computer-based laboratory tools, the curriculum, and the social and physical setting. These characteristics are: (1) Students focus on the physical world. (2) Immediate feedback is available. (3) Collaboration is encouraged. (4)

Powerful tools reduce unnecessary drudgery. (5) Students understand the specific and familiar before moving to the more general and abstract. In addition, these computer-based laboratory tools give students more control over their learning since they may select which measurements are to be made and the way in which the data are to be displayed.

The current study is part of an ongoing attempt to uncover further student difficulties in understanding basic motion concepts via interpretation of kinematics graphs. Researchers continue to develop ways to modify instructional delivery systems to better reach a growing group of diverse learners. No matter what type of instruction is used, Arons (1990) is sure to remind us that:

> The gaps in understanding *cannot* be fully resolved for all students on the first passage through kinematics, even with better exercises and tests. Genuine learning of abstract ideas is a slow process and requires both time and repetition. Repetition without intervening time yields meager results. The most efficient approach is to move on through the subject matter but to keep returning and reinvoking the kinematical concepts in concrete, intuitive ways at every opportunity. As the ideas are reencountered in increasingly rich contexts, they are gradually assimilated - but at different rates by different individuals. (p. 38)

Effective instruction includes giving students a variety of ways of looking at the same concepts. The use of interactive digital video can provide students an additional mechanism through which to learn basic kinematics concepts. Interactive digital video techniques also provide an opportunity for students to investigate ideas and concepts on their own, leading to increased learner control.

Statement of the Problem

Computers, laser discs, compact discs, and interactive video techniques are all examples of technology that will be a part of the framework for curriculum development in the coming century. In terms of evaluating the role that computer-based learning has played in higher education. Wills and McNaught (1996) cautioned that speculation remains regarding the potential of the computer to change the nature of teaching and learning. These researchers also noted that teaching can change because the computer provides a potentially powerful and flexible alternative mode of instructional delivery. Furthermore, learning can change because the focus of instruction can increasingly be on access to and management of knowledge, rather than on simple rote acquisition of knowledge.

Although the technology is present and continues to grow and develop in complexity, one underlying question must be asked. For students with different learning styles, do these various technological tools, when used in the classroom and laboratory settings, lead to increased learner understanding of basic kinematics concepts? This question provided the impetus for this study.

A theoretical framework specific to interactive digital video instruction has not been developed. My contention is that more studies must be conducted for the physics education research community to be able to formulate a framework by which the assessment of these growing technologies can be performed. The intent of this research paper is, in part, to contribute to this growing body of understanding students' "knowing of physics" (Fuller, 1993) and to contribute to the development of a theoretical framework through which interactive digital video tools can be assessed in terms of their unique pedagogical attributes.

Along with the development of curricula that utilize multimedia tools to aid student understanding of basic kinematics concepts, attention must be paid to research on student learning and cognition which includes studies of student misconceptions. A more detailed discussion of research in these areas as well as a brief discussion of teaching for conceptual change is presented in Chapter 2.

The present study builds upon the somewhat limited results of past research conducted in the area of student understanding of basic kinematics concepts using an interactive digital video technique. The interactive digital video technique used in this study is a *Toolbook* application called VIDSHELL (Davis. 1995). VIDSHELL is a self-contained application that enables students to bring in and analyze data that they have captured using a video camera, video capture board. and corresponding software. Of interest is the comparison of student learning of kinematics concepts between students who received traditional laboratory instruction versus those who received laboratory instruction utilizing interactive digital video techniques.

One focus of this study was to assess students' understanding of basic kinematics concepts via the interpretation of motion graphs. To this end the Test of Understanding Graphs-Kinematics (TUG-K) was used (Beichner, 1994). This instrument is described in the next chapter and is shown in Appendix A. Additional emphasis was placed on naturalistic inquiry methods in the actual laboratory setting to assess further students' learning of basic kinematics concepts as well as their ability to interpret motion graphs. These type of inquiry methods involve studying real-world situations as they unfold naturally without manipulation and control (Patton, 1990, p. 40).

An additional focus of this study involved the assessment of student learning styles. Several researchers have suggested that these interactive multimedia and computer-based laboratory techniques better accommodate a diverse group of learners. In his work with the development of the Comprehensive Unified Physics Learning Environment (CUPLE) project Wilson (1994. personal communication) indicated that this type of technology serves to reach a greater number of students with diverse learning styles. Wilson also indicated that an assessment of student learning styles would be valuable in an effort to determine whether some students with particular learning styles are better served by this form of instruction. Brungardt & Zollman

(1995) noted that further studies into the kinesthetic nature of various computer-based laboratory tools are warranted.

Research on the learning effects of various multimedia tools suggests that, overall, they are more palatable to a broad range of students. One contention of this researcher is that if these various multimedia tools appeal to a broad range of students, they may appeal to a wide range of student learning styles. Of interest then is the assessment of student learning styles to determine possible relationships between particular individual learning style strengths and multimedia instructional methods.

The Dunn and Dunn Learning Style Model[1] was used in this study and is described in Chapter 2. The model is shown in picture form in Appendix B. The learning style assessment instrument that was utilized in this study is the Productivity Environmental Preference Survey (PEPS)[2] which was designed and developed by Price, Dunn, & Dunn (1991). A copy of the Productivity Environmental Preference Survey can be found in Appendix C. Of particular interest in this study were students' learning style scores on the auditory, visual, tactile, kinesthetic, motivation and structure elements of the assessment. The auditory, visual, tactile and kinesthetic elements can be collectively referred to as modality elements. The Productivity Environmental Preference Survey as well as the associated scoring system is described in detail in Chapter 2.

In her investigations with learner control using computer-aided instruction, Gay (1986) stated "Efforts should continue to develop and test models for learning systems that have the capability to adapt to individual learners' needs" (p. 227). In addition, Burwell (1991) reported that "... issues such as learner control, use of cuing strategies, or learning styles and their impact upon computer-assisted learning are not widely reported in the research literature" (p. 37). Burwell argued that these issues become increasingly relevant as the use of technology in our educational system grows.

The purposes of this study were:

1. To study the role that individual learning styles play in relation to students' knowledge of basic kinematics concepts presented in the laboratory setting using both traditional and interactive digital video techniques. A primary focus here was on students' knowledge of basic kinematics concepts as evidenced by their ability to interpret motion graphs.

2. To examine students' conceptions regarding basic kinematics concepts. Further, to compare the effects of laboratory instruction that utilizes interactive digital video techniques versus more traditional techniques on student learning and understanding of basic kinematics concepts. A particular focus was the assessment of student ability to interpret motion graphs following laboratory instruction that utilized these instructional techniques.

Research Hypotheses and Questions

To address Purpose 1 the following hypotheses were formulated:

1. A significant difference will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and score on the auditory, visual, tactile, kinesthetic, motivation, and structure elements of the Productivity Environmental Preference Survey are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

2. A significant relationship will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and score on the auditory, visual, tactile, kinesthetic, motivation, and structure elements of the Productivity Environmental Preference Survey are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

To address Purpose 2 the following hypotheses were formulated:

3. A significant difference will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and course grade are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

4. A significant relationship will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and course grade are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

A significance level of 0.05 was adopted for decision making purposes as is customary with exploratory studies. There is fairly common agreement on a significance level of $\alpha = 0.05$ to define the region of incompatibility for the *F* distribution (Keppel, 1991, p.51).

Other research questions include:

1. Do students with certain learning style strengths (i.e. auditory, visual, tactile, kinesthetic, motivation or structure) as measured by the Productivity Environmental Preference Survey respond better to laboratory instruction via interactive digital video or traditional techniques?

2. How do students' perceptions of their learning styles compare to their scores on the Productivity Environmental Preference Survey?

3. What is the overall relationship between students' learning style strengths and instructional techniques?

4. Does instruction using interactive digital video techniques contribute to student motivation to learn physics? If so, does this enhanced motivation to learn translate into improved performance and enhanced understanding?

These research questions were addressed using quantitative as well as qualitative investigative techniques. Quantitative data were obtained from students' scores on the Test of Understanding Graphs-Kinematics and the Productivity Environmental Preference Survey. Qualitative data were obtained from observations, student writing activities, and performance on questions related to kinematics and graphing given after students had completed each of two laboratory exercises.

Limitations of the Study

Limitations of this study are identified as follows:

1. The assessment of students' understanding of motion is limited to their ability to interpret motion graphs even though many other motion concepts were taught during this study.

2. Students may be reactive to the "new" technology using video cameras and interactive digital video techniques in the laboratory (i.e., potential for Hawthorne effect is present).

3. Students may have reactive effects to the type of instruction to which they are exposed as a result of being pretested for their individual learning styles. Thus, some students may be more sensitized to the instructional conditions.

4. Individuals who are bright and flexible are possibly more able to persist in existing methods of instruction (Price & Griggs, 1985). These individuals may therefore do well in any learning situation. Hence, some students may have the abiltity to do well with either of the instructional techniques employed.

5. A potential exists for "compensatory rivalry" (Cook & Campbell, 1979, pp. 54 - 55) between students instructed using traditional techniques and those instructed using interactive digital video techniques. No strategy exists to prevent students from discussing the experiments among themselves outside of class. Students were therefore aware of the different instructional methods utilized for each group.

Assumptions Underlying the Study

The following assumptions were made by the investigator prior to commencement of the study:

1. Interaction among students in other sections of the *Physics for the Modern World* course and its associated laboratories would have little effect on their performance in this study. There were four additional laboratory sections within a separate lecture section of this course that were not a part of this study.

2. Students enrolled in each laboratory section are representative of a typical cross-section of students enrolled in the course.

Significance of the Study

This study investigated students' ability to understand basic kinematics concepts following laboratory instruction using both traditional and interactive digital video techniques. Although research has attempted to understand students' formulation of these basic concepts using a variety of traditional instructional strategies, efforts have only recently emerged which bring to bear the effect of new technologies on the overall learning process. This study allowed the investigator to compare student learning of basic kinematics concepts through the use of both traditional laboratory instruction and instruction that incorporated interactive digital video techniques.

Several researchers have suggested that learning styles were factors in their results (e.g. Beichner. 1990; Brasell. 1987; Redish, 1994; Zollman. 1996). However, no research studies on using new technologies in physics teaching include as a component a formal assessment of student learning styles. In a discussion of the design of various instructional strategies using interactive video. Hannafin & Phillips (1987, p. 45) argued that "Little attention has been focused on the role of the *individual* in learning from interactive video." The current study aimed to determine the role that *individual* learning style differences have on students' ability to understand basic kinematics concepts based on instruction that utilized interactive digital video techniques.

Much of the research regarding the use of some form of multimedia technique to teach physics has concentrated on the introductory calculus-based course for physics and engineering majors. In addition, some studies have been conducted with high school physics students and "special" groups of students enrolled in introductory level college courses, such as pre-service elementary teachers. This study is significant, in part, because it focused exclusively on those students enrolled in a typical introductory physics course for non-science majors.

Summary

This chapter outlined the proposed investigation of the influence that laboratory instruction using interactive digital video techniques may have on student understanding of basic kinematics concepts. A discussion was presented regarding the use of formal learning style assessments to understand the role(s) that student learning styles may play in terms of students' development and understanding of kinematics concepts following instruction utilizing both traditional as well as interactive digital video techniques. Research problems as well as assumptions and limitations of this study were also outlined in this chapter.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter begins with a general description of physics classrooms and laboratories (past and present) followed by discussions of conceptual change and its role in physics learning; student cognition and learning in physics; student learning styles; and multimedia and computer-based techniques and their impact on student cognitive development. The discussion of conceptual change focuses on the role conceptual change plays in terms of students' understanding of basic kinematics concepts. Within the discussion of student cognition, attention is given to the development of student conceptions in physics. A review of the literature on student learning styles is also presented. A key focus of this section is the review of research related to uncovering the role(s) that learning style assessment can play in terms of the modification of instructional delivery systems to include multimedia techniques to accommodate better a diverse group of students. A discussion is also presented regarding a review of research relating to the impact that utilization of instructional techniques that involve various kinds of multimedia tools have on student cognitive development. The role(s) that multimedia techniques play in terms of student understanding of kinematics graphs is discussed.

The Physics Classroom and Laboratory (Past and Present)

Traditionally, physics is taught in a typical lecture-style format in which the teacher provides information to the students by talking to them. Visual stimuli in a traditional classroom typically include notes written by the teacher on a chalk board or overhead projector and occasional demonstrations of the phenomena. This style of instruction focuses on the instructor, the only active participant in the class. Hence, in a traditional classroom, students are often passive participants. Although optimum for some students, this mode of instruction is deficient in many ways for others. One outgrowth of much research in physics learning is the basic idea that in order for meaningful learning to occur, the learner must be given an opportunity to interact actively with the material to be learned (Larochelle & Desautels, 1992; Niedderer, Goldberg, & Duit, 1992; Scott, 1992).

Laws (1988) summed up the typical experience of students in an introductory course when she said "... taking introductory physics is like trying to take a drink from a fire hose" (p. 23). With this statement Laws emphasized the typical cognitive overload experienced by the average student in an introductory course. Laws also suggested that too many topics are included in an introductory course to possibly do justice to any of them. Further, Laws concluded that many of these topics require students to make substantial paradigm shifts from their own world view to the basic world view of classical physics. Failure to make this paradigm shift often leaves students in a state of cognitive disequilibrium. In essence, this cognitive overload does not permit students to make true meaning out of the learning experience. In fact, Laws (1991b) later concluded "This gap between the complexity of physics lecture topics and abilities of most students leads them to copy mindlessly whatever is on the board in hopes that they might be able to figure it out before the next exam" (p. 22).

Ausubel (1968) provided a description of meaningful learning by stating "Meaningful learning presupposes *both* that the learner manifest a meaningful learning set, that is a disposition to relate the new material nonarbitrarily and substantively to his cognitive structure, and that the material he learns be potentially meaningful to him, namely, relatable to his structure of knowledge on a nonarbitrary and nonverbatim basis" (p. 38). Ausubel also purported that many students develop a rote learning strategy because of their anxiety levels toward learning a subject. Further, a general lack of self-confidence on the part of an individual to learn meaningfully makes it easier to just rotely memorize information rather than to try to understand it. Ausubel further asserted that whether a learning task is potentially meaningful depends on two factors: the nature of the material to be learned, and, the nature of the particular learner's cognitive structure. Ausubel stated that "... insofar as meaningful learning outcomes in the classroom are concerned, the availability, and other significant properties, of relevant content in different learners' cognitive structures constitute the most crucial and variable determinants of potential meaningfulness. Thus it follows that the meaningfulness of learning material varies not only with prior educational background, but also with such factors as age, IQ, occupation, and social class and cultural membership" (p. 40). The more traditional form of instruction is not typically grounded in students' real life experiences and thus does not effectively facilitate the process of meaningful learning.

Ausubel's ideas regarding meaningful learning form part of the foundation of the constructivist theory of knowledge and learning. Fosnot (in Brooks & Brooks (1993)) stated that learning from a constructivist perspective "... is understood as a self-regulated process of resolving inner cognitive conflicts that often become apparent through concrete experience, collaborative discourse, and reflection" (p. vii). Constructivism, although not a theory of teaching, serves as a basis for many changes and reforms currently evolving in science and physics education. Advocates of constructivist teaching support what Kyle, Abell, and Shymansky (1992) referred to as starting instruction with "where the learner is." This parallels Ausubel's ideas regarding meaningful learning relative to the importance of ascertaining what the learner already knows.

With these ideas in mind, current research in physics education is carried out. In the Workshop Physics program, physics is essentially taught without lectures (Laws, 1991b). Laws (1988) suggested that most students in introductory courses at the high school and college levels simply do not have sufficient concrete experience with everyday phenomena to be able to comprehend fully the mathematical representations typically demanded of them in these introductory courses. Laws (1991b) further indicated that a considerable body of literature exists which discusses the limitations of traditional lectures. She stated "Skilled lecturers are good at transmitting information and at motivating students to study the topics covered in a lecture, but there is not good evidence that lectures or lecture demonstrations are efficient vehicles for helping students learn how to think critically, understand difficult concepts, or solve problems" (p. 22).

In Workshop Physics the learner is the center of the activity and is therefore an active participant in the learning process. Workshop Physics offers students the opportunity to observe phenomena, analyze data, and develop verbal and mathematical models to explain their observations. This approach affords students the opportunity to translate a concrete experience with a scientific explanation.

Conceptual Change and its Role in Physics Learning

What do we want our students to know and be able to do after a semester or two of introductory physics? This question may sound simple, but is actually rather challenging. Once we have determined what we want our students to know, we must figure out a way to help him/her learn it. The issue is not as simple as describing the motion of an object as it moves from point A to point B! Tobias (1992) suggested that for the physics community as a whole, the question really becomes "what works?" In answering this question Tobias described as one of the most challenging issues discovering what works best, first theoretically and then practically, as curricular and instructional strategies.

To get at the real root of "what works" in the physics classroom, a fundamental understanding of the role that conceptual change plays in physics teaching is needed. Furthermore, a deep understanding of "what works" is more than the intuition of physics educators which Hammer (in press) described as being borne out of their extensive but unstudied experience as students and as teachers. On the other hand, Hammer offered that educational research has yet to achieve theories with the precision, coherence, and stable consensus that would warrant faithful commitment by instructors. Hammer further posited that because of this lack of proven methods or clear principles, we need to rely substantially on instructors' perception and judgement.

When students enter the physics classroom they bring with them their personal world views. Individuals form their understanding of the world around them based on their own personal life experiences. The challenge for physics instructors is to help students uncover what part or parts of their world views are scientifically sound and which are not. This process of discovery is, in part, the essence of conceptual change teaching. The part of students' world views which are not scientifically sound are referred to by many researchers as misconceptions. Misconceptions are generally thought of as those conceptions that students bring with them into the classroom that essentially differ from that of the scientist. Other terms are also used to describe student misconceptions such as "preconceptions," "naive conceptions," and "alternative conceptions." Regardless of the term used, Hammer (in press) points out that the core idea is of *conceptions* that

> 1) are strongly held, stable cognitive structures;
> 2) differ from expert conceptions;
> 3) affect in a fundamental sense how students understand natural phenomena and scientific explanations; and
> 4) must be overcome, avoided, or eliminated [in order] for students to achieve expert understanding. (p. 7)

Although considered by some to be more judgmental than the other descriptive terms, the term misconception will be used throughout this research paper for the sake of clarity and continuity.

Conceptual change is important in physics learning because each student sees the world through his/her own lens. Dykstra (1992) revealed that presenting students with a Newtonian view of the world is usually not enough for students to reach the point where they are able to change the way they think about how the world works. Providing students with learning situations that afford them the opportunity to wrestle with concepts on their own is vital. As a result, students often experience "cognitive disequilibrium" or "cognitive dissonance," as their existing schemas or world views are challenged. In this state of discomfort the learner recognizes existing schemata that are inadequate to explain the experience (Appleton, 1993). Scott, Asoko, and Driver (1992) described strategies that can be used to promote conceptual change. The first centers around the issue of cognitive conflict and ways that conflicting perspectives can be resolved. The second considers strategies (such as use of metaphors and analogies) which facilitate the construction of ideas that start by building upon learners' existing ideas. These researchers discussed several teaching techniques designed to bring about conceptual change. An example of one such technique is the connection of new topics via linkages to other "real world phenomena." Putting unfamiliar material into a familiar context is helpful in terms of promoting conceptual change.

Hewson (1996) stated "Much of what students do is to learn things they didn't know by making connections to what they already know: this is not a problem when students' present views are consistent with what they learn" (p. 132). When their present views are inconsistent with what they are attempting to learn, students must confront their current beliefs on their own. This process of confrontation is much more than simply telling students what the right answer is. If true learning is to occur, students must be able to make sense of new concepts on their own terms. The effort to make sense of new concepts takes time, and, according to Appleton (1993) "... the new structure would need to be used and tested in a variety of situations to be useful and accessible" (p. 269). Appleton further indicated that students will often times need assistance in interpreting new information and in making sense of it. Thus, the teacher's role as well as the role of the learning tools, is vitally important in the process of schema development (or redefinement, as the case may be).

Hewson and Hewson (1992) described a conceptual change model which has two components. The first component consists of the *conditions* that need to be met (or no longer met) in order for a person to be able to experience conceptual change. The second is the individual's *ecology* which essentially provides the context in which the conceptual change occurs.

A person who is overweight must decide for him/herself when the time is right to diet and exercise so that weight loss will occur. Likewise, only when a learner decides (either explicitly or implicitly according to Hewson & Hewson) the conditions have been met can conceptual change actually occur. Learning is a process that demands the learner be an active participant. Hewson & Hewson presented the conditions that apply to conceptual change learning as follows:

> 1) *Is the conception intelligible to the learner?* In other words, does it make sense to the learner? Does the learner know what it means?
> 2) *Is the conception plausible to the learner?* If the conception is intelligible to the learner, then does he/she also believe that it is true?
> 3) *Is the conception fruitful for the learner?* That is, if a conception is intelligible and plausible to the learner, does it also achieve something of value for him/her? (p. 60)

These conditions parallel Ausubel's conception of meaningful learning as discussed earlier. Strike & Posner (1992) add another condition, which they place first on this list. "There must be dissatisfaction with current conceptions" (p. 149). Much of the time. people will not alter conceptions that have worked all of their lives unless they reach a point in which they are personally able to view their existing thinking as dysfunctional or inadequate.

Van Heuvelen (1991a) emphasized that students often leave the physics classroom with the same preconceived notions or misconceptions that they had when they entered. and. further noted that students' knowledge often consists of a limited number of random facts and equations that have little conceptual meaning. He then asked "What changes in emphasis and in pedagogy can we make to address these deficiencies in student achievement following conventional instruction" (p. 891)? He posited that the traditional lecture as practiced in most physics classrooms assumes students can learn from clearly presented knowledge.

An outgrowth of his research is "Overview, Case Study Physics" (Van Heuvelen. 1991b). This technique offers students the opportunity to analyze problems and processes in a fashion similar to that used by scientists and experts. Students are encouraged to actively construct knowledge using a "knowledge hierarchy" which forms its basis in qualitative understanding.

Student Cognition and Learning in Physics

Research within the cognitive domain involves studies that regard the complex sequences through which an individual begins to learn, then understand and process new and difficult information. Of additional interest is understanding how students use their existing knowledge as they attempt to learn and understand new information. Studies of human cognition have emerged in recent years within the community of physics education researchers. According to Larkin (1981), "The basic view is that human cognition consists of the sophisticated processing of immense amounts of information, both information coming into the system through sensory organs and information stored internally in the brain" (p. 534). Coming to terms with these processes of human cognition as they relate to student learning and understanding, then, is essential.

Redish (1994) succinctly stated "If we are to make serious progress in reaching a larger fraction of our students, we will have to shift our emphasis from the physics content we enjoy and love so well to the students themselves and their learning" (p. 802). Redish further noted that he is no longer just concerned about the content he is covering in his physics classes. Rather, he is careful to pay attention to how students are interacting with the content. Redish suggested that as teachers we want our students to build their understanding of the content into an accurate and effective mental model. He defined the term *mental model* as the collection of mental patterns people build to organize their experiences related to a particular topic (p. 797). For most individuals, the development of a mental model occurs through a process of making connections between new information to be learned and past personal experiences.

Niedderer and Schecker (1992) provided a description of a theoretical model which could be used as a guide in the analysis and interpretation of student understanding and learning in physics. They made an important distinction between *thinking* and *learning*:

> 1) *Thinking* is described as processes of the mind using *existing* cognitive elements (conceptions, beliefs, frameworks, knowledge) in a new context.
> 2) *Learning* is described as the *change* of elements or the change of cognitive processes using cognitive elements, which result from developmental processes of the cognitive system interacting with external situations. *Learning* is seen as *stable changes* in the cognitive system which allow one to explain stable changes in the individual's behavior. (p. 75)

These researchers asserted that it remains to be investigated how "stability" evolves. The crux of the issue is that as an individual attempts to learn, he/she must go through a mental process to reach a point where a previous conception can be discarded and replaced with a new one.

Niedderer and Schecker also suggested that generally for *thinking* processes, no changes occur in an individual's "deep structure" (includes stable elements such as ideas, schemes, concepts and networks) of their cognitive system. Essentially an individual develops current constructions based on cognitive elements that were developed previously but are now being utilized in a different way. The spontaneous construction of perception and meaning are relevant in terms of both the process of thinking and the process of learning.

A look at how students respond to physics instruction, particularly when presented with novel situations, is of interest. Students tend to look for similarities in problems or cluster them into groups based on their "cosmetic" features rather than by what physics concepts can be applied. Minstrell (1992) found that students' knowledge systems appear conservative and essentially resist change. Because of this reluctance to change, Minstrell suggested that students will frequently miss inconsistencies between their present beliefs and the results of classroom or laboratory instruction. In fact, Minstrell stated "If students do not recognize an inconsistency, they often reject the new result or new idea, perhaps because it is too discrepant or not sufficiently interesting. Often the new idea is rejected because the students doubt their own experimental abilities, doubt the validity of the tools or the methods used, or doubt the reliability or repeatability of the results" (p. 121). What happens as a result is that students' *deep structure* within their cognitive systems never ultimately changes.

Reif and Larkin (1991) looked at knowledge structure and knowledge organization and the overriding consequences for student learning. They clearly noted that students' conceptions of understanding have far-reaching implications for their learning. Reif and Larkin suggested that students' conceptions for understanding determine their "... learning goals and how they focus their attention. Students' conceptions also determine when students are satisfied with their own learning and cease further efforts" (p. 743). In fact, Reif and Larkin indicated that students often do not even attempt to reach a goal of scientific understanding and thus their acquisition of knowledge is inert, rather than flexibly usable. These researchers suggested empirical investigations that included systematic interviews would be useful to aid in the identification of students' conceptions of the goals of science and of the thought processes that they think would be useful for science. Furthermore, they indicated that besides systematic interviews that focus on verbal reports of students' conceptions, observations of students' behavior may be useful. Reif and Larkin also suggested making comparative observations of individual students to ascertain how the same students approach cognitive tasks (such as concept learning or problem solving) in both everyday contexts and within the scientific domain.

Mestre and Touger (1989) outlined the differences between the knowledge organization of the "expert" and "novice" in physics, when the terms refer to the degree of skills and knowledge. These terms do not imply a continuum regarding general proficiency or success in life. Regarding knowledge organization, experts tend to gather and store information in clusters or chunks similar to a hierarchical pyramid. Within this pyramid, fundamental concepts occupy the highest level and domain-related, factual information the lowest level. Mestre & Touger suggested that "Within this hierarchical arrangement, being an expert, or 'knowing more' means having: (a) more conceptual chucks in memory, (b) more relations or features defining each chunk, (c) more interrelations among chunks, and (d) effective methods for retrieving related chunks" (p. 452).

Mestre and Touger also outlined differences between experts and novices in their approach to problem solving. They cited from cognitive research studies that experts tend to begin to solve a problem by focusing on a problem's "deep structure" (i.e. principles, concept, or heuristics that could be applied to solve the problem) to gain clues as to which concept(s) and/or principle(s) they should apply to solve it. Once the concept(s) have been selected. an expert would then qualitatively analyze the problem. On the other hand. a novice problem solver tends to cue in on the more superficial and cosmetic features of a problem. Novice problem solvers tend to get bogged down with the language and jargon used in physics. Furthermore, a novice problem solver would tend to just "plunge" right in toward a solution with little or no thought given to the strategy. Mestre and Touger suggested giving students tasks that involve problem categorization and qualitative explanations as a means of providing teachers a vehicle through which to measure students' understanding of physics.

Walsh, et al. (1993) advocated the need for students to develop both quantitative and qualitative understandings of concepts and principles. They argued "Although accuracy and reliability in solving quantitative problems is necessary, a qualitative understanding enables students to apply those concepts and principles to new problems and in real-life situations" (p. 1133). Moreover, a deeper qualitative understanding should also strengthen the problem solving ability of the novice and move them closer to the domain of the expert problem solver. Snider (1989) asserted that very few studies of teaching and learning, especially the kind that lead to insights that can advance teachers' ability to cultivate problem solving abilities in their students, are actually occurring in high school and college physics classrooms and labs. Snider further articulated the need to continue this type of research "... at whatever level of complexity is feasible and appropriate. Such investigative efforts cannot fail to have a positive impact on physics instruction in general and on the promotion of problem-solving ability in particular" (p. 63).

Arons (1981) indicated that students in introductory physics courses display very basic cognitive difficulties. He further asserted that instructional materials have not traditionally been of much use in helping students overcome these difficulties. Since

Arons made this point over a decade ago, much of the development of instructional methods and materials has focused on students' cognitive difficulties in learning physics. At the present time, instructional materials are being developed by researchers to address these learning difficulties. Certainly, the development of multimedia tools to learn physics is one such example. What remains to be seen is the impact that tools and technologies such as interactive digital video have on student cognition and learning. This study, in part, addressed the issue of how this relatively new technology might aid students in their learning of basic kinematics concepts.

The development of an understanding of human cognitive processes can be facilitated through the use of various qualitative data collection techniques. As Guba and Lincoln (1989) suggested, "... given that the human instrument is to be employed, the question of which methods to use is easily answered: those that come most readily to hand for a human. Such methods are, clearly, qualitative methods" (p. 175).

Furthermore, as we look at the growing diversity in the clientele who enroll in our courses, we must also recognize the need to address formal assessment of student learning styles. Certainly understanding how students come to know what they know could be enhanced through the lens of assessment of learning styles.

Student Learning Styles

Learning Styles Described and Defined

What exactly is a learning style? Keefe has worked to present a research base for learning styles that would make it more practical for teachers as well as researchers (Oregon School Study Council Bulletin, 1987). He defined learning style as being characteristic of the cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment. Keefe and Ferrell (1990) further summarized learning style as a complexus of related characteristics in which the whole is greater than its parts. Learning style is a gestalt combining internal and external operations derived from the individual's neurobiology, personality, and development and reflected in learner behavior. Learning style also represents both inherited characteristics and environmental influences.

Dunn (1990) described learning style as "... the way each learner begins to concentrate, process, and retain new and difficult information" (p. 224) She noted that this interaction occurs differently for everyone. Dunn also highlighted that "To identify and assess a person's learning style it is important to examine each individual's multidimensional characteristics in order to determine what will most likely trigger each student's concentration, maintain it, respond to his or her natural processing style, *and* cause long-term memory" (p. 224). To reveal these factors, the learning style model must be comprehensive.

Dunn (1982) noted that the uniqueness of individual learning styles can be thought of as a fingerprint. She said "Everyone has a learning style, but each person's is different - like our fingerprints which come from each person's five fingers and look similar in many ways" (p. 27). Later she noted that a person's learning style is as unique as a signature (Dunn et al., 1989). Interestingly, Sternburg (1990) said "Styles, like abilities, are not etched in stone at birth." Dunn (1986) noted that a person's style can change over time as a result of maturation. Dunn (1996a) reported:

> In 1979, Armin Thies of Yale University was the first to report that at least three-fifths of the Dunn and Dunn Learning Style Model elements are genetically imposed. For example, individual responses to learning with: Sound versus Quiet, Soft versus Bright Lighting, Warm versus Cool Temperatures, and Formal versus Casual Seating are biological. Also genetic in origin are Perceptual Strengths (auditory, visual, tactile and kinesthetic), learning with or without Intake (snacks), Time-of-Day energy high and lows, and Passivity versus Mobility needs. Conversely, Thies determined that the sociological preferences for Learning Alone, with one or more friends, with an authoritative versus a collegial teacher,

> and for being comfortable with patterns and routines as opposed to preferring a variety of instructional resources, develop over time through each person's experiences and therefore, are developmental. Thies perceived that Motivation, Responsibility (which correlates with conformity/non-conformity), and external versus internal Structure are also developmental. (p. 82)

Dunn contended that strong preferences can change only over a period of many years and that preferences tend to be overcome only by high levels of personal motivation.

Dunn further asserted that teachers cannot identify students' styles without the use of appropriate instruments. Assessing a person's unique style is vital to the teaching/learning process. Dunn also asserted that a match between a student's style and a teacher's style will lead to improved student attitudes and higher academic achievement. The Dunn and Dunn Learning Style Model was used in this study and is described in detail in the following section. The model is also shown in picture form in Appendix B.

Description of the Dunn and Dunn Learning Style Model

Many different learning style assessment models and instruments are available. De Bello (1990) indicated some models are multidimensional, encompassing cognitive, affective, and psychological characteristics, and others are limited to a single variable, most frequently from the cognitive or psychological domain. Some learning style instruments as described by De Bello include those of several theorists including Dunn & Dunn, Hill, Letteri, Ramirez, Reinert, Schmeck, Hunt, Kolb, Gregorc, and McCarthy.

Price, Dunn, and Dunn (1991) suggested that productivity style theorizes that each individual has a biological and developmental set of learning characteristics that are unique. They further suggested improvements in productivity and learning will come when instruction is provided in a manner that capitalizes on an individual's learning strengths. As a model. Price. et al. indicated that productivity style embraces several general principles which they state in the form of philosophical assumptions:

> 1) Most individuals are capable of learning.
> 2) The learning conditions in which different individuals learn best vary extensively.
> 3) Individual learning preferences exist and can be measured reliably.
> 4) Most students are self-motivated to learn when they have the option of using their learning style preferences and experience success.
> 5) Most teachers can learn to use individual learning styles as a basis for instruction.
> 6) When selected teachers are not capable of learning to use individuals' learning styles as a basis for instruction, students can be taught to teach themselves and. thus. bypass their teachers' styles.
> 7) Use of individual learning style strengths as the basis for instruction increases learning and productivity. (pp. 21 -22)

As De Bello noted. the basic tenet of the Dunns' model is that individual styles must be assessed, and. if a student is to have the best opportunity to learn. instructional techniques must be used that are congruent with each student's style. Not all theorists agree with this tenet because they feel it is extreme. Other theorists wrestle with the question of whether we should teach to an individual's strengths or try to help them develop their weaknesses. The best answer may be both. One of the best ways. especially in large classes. to teach to individual students' strengths is to use a variety of instructional styles and modes of delivery.

The learning style assessment instrument chosen for this study is the Productivity Environmental Preference Survey by Dunn. Dunn. and Price (see Appendix C). This instrument was chosen because of its comprehensive nature, and, because of the relative ease of assessing students and interpreting the results. The Productivity Environmental Preference Survey was developed from the Dunn and Dunn Learning Style Model and is described in the following section. The Dunn and Dunn Learning Style Model is based on five different categories: (1) Environmental. (2) Emotional. (3) Sociological. (4) Physiological. and (5) Psychological. These categories provide the basis for the elements displayed in the feedback profile obtained after student responses to the Productivity Environmental Preference Survey have been scored.

Description of the Productivity Environmental Preference Survey (PEPS)

In summarizing the categories of the Productivity Environmental Preference Survey, one finds that the emotional category has elements of motivation, persistence, responsibility and structure. The sociological category has elements that assess whether an individual prefers to work alone or in a group, whether feedback from an authority figure is preferred, and whether variety enhances learning. The physical category provides information regarding an individual's perceptual modality preferences (i.e. auditory, visual, tactile and kinesthetic). The physical category also includes items like preference for intake while learning and preference for best time of day. Finally, the psychological category allows one to make interpretations regarding cognitive processing (i.e. global versus analytic processing). Research studies have found that the elements of sound, light, temperature, design, perception, intake, chronobiological highs and lows, mobility needs, and persistence appear to be biological in nature. Sociological elements as well as motivation, responsibility (i.e. conformity), and need for structure are thought to be developmental in nature.

The Productivity Environmental Preference Survey consists of 100 questions on a Likert scale. The scoring system for the PEPS instrument uses standard scores which range from 20 to 80. The scale is further broken down into three categories which will be referred to in this study as Low, Middle and High. The Low category represents standard scores in the 20 - 40 range; the Middle category scores in the 41 - 59 range; and the High category scores in the 60 - 80 range. Individuals who have scores lower than or equal to 40 or higher than or equal to 60 for a particular element find that variable important when they are working. Individuals who have scores in the Middle category find that their preferences may depend on many factors. For example, individual preferences falling into the middle range may be dictated by other items such as motivation and interest in the particular topic area being studied. A sample results profile given to each student participating in this study after completion of the Productivity Environmental Preference Survey is found in Appendix D. More detailed information regarding result interpretation is also found in Appendix D. This information is useful both for teachers and students. Students can be instructed to capitalize on their learning strengths and build upon their weaknesses.

Looking at one example, within the category of environmental stimuli are the elements of sound, light, temperature and design (formal versus informal). The elements within this category are self-explanatory. This category is one that is difficult to accommodate in the classroom. However, learners can easily satisfy their preferences when working outside of class. For example, a score ≥ 60 for the element of sound would mean that an individual has a preference for sound when learning new and difficult information. An individual could accommodate their preference for sound by listening to soft music. A score ≤ 40 on the sound element would imply that an individual does not show a preference for sound and thus should work in a quiet environment (using earplugs if necessary). A score in the middle category means an individual might prefer sound at one time, and not at another. In this case an individual's preference would depend on other factors.

Once the Productivity Environmental Preference Survey has been administered, students should receive this feedback profile as quickly as possible. The standardized scores (ranging from 20 to 80) that form the basis for an individual's learning style profile may be easily misinterpreted. Students immersed in an academic environment may tend to interpret a higher score as being better than a lower score. Students must immediately be made aware that no high or low exists on this scale in terms of superiority of scores. Furthermore, no scores are ever bad scores - all are simply unique. The message to the student must be clear: learning styles are unique to the individual and are not to be labeled as being good or bad. No scientific evidence shows that one type of learning style is academically superior over others.

Numerous research studies ("Research based", 1990) have documented the reliability and validity of the Productivity Environmental Preference Survey. Dunn and Dunn (1993) posited that research on their model is more extensive and more thorough than research on many educational topics. As of 1992 research utilizing their model had been conducted at more than 70 institutions of higher education, at all levels K - college, and with students at most levels of academic proficiency, including gifted, average, underachieving, at-risk, dropout, special education, vocational, and industrial art populations.

Dunn, et al. (1995) performed a meta-analysis of the Dunn and Dunn model of learning style preferences. They reviewed forty-two different experimental studies conducted with the model from 1989 to 1990. Of the forty-two studies, six were omitted because evidence suggested possible threats to their validity based on the criteria of Campbell and Stanley (1966). The thirty-six remaining studies involved more than 3,000 subjects. The selected studies all examined the effects of congruent versus dissonant treatments on learning style preferences. Each of the studies were coded based on the following: (a) study characteristics; (b) instrument type; (c) sample characteristics; (d) setting; (e) instructional factor; (f) methodological procedure; (g) outcome measure; and (h) attitude. Summary statistics (such as means, standard deviations, F ratios, t-tests and chi-squares) were converted to a common measure of effect size. Further transformations of the statistics reported in these studies were done to compute a correlation coefficient that would serve as a measure of effect size. The end result produced 65 different effect sizes or comparisons. When these effect sizes were combined, the overall weighted value of *r* (i.e. correlation coefficient) was .353, with a residual variance of .079. This was converted to a mean standard deviation of .755. These results indicated that overall academic achievement of students whose learning styles have been matched can be expected to be about three-fourths of a standard deviation higher than those of students whose learning styles have not been accommodated (Dunn, et al., 1995). Further, when instruction is compatible with students' learning style preferences, the overall learning process is enhanced.

Dunn, et al. (1995) suggested the need to identify individual learning styles as a basis for providing responsive instruction has never been more important than it currently is. Instruction responsive to individual learning styles is especially critical as the pool of students who enroll in our classes continue to become more and more diverse. No studies reported in the literature involving introductory physics students have used this learning style assessment tool.

Learning Styles and Classroom Instruction

Kolodny (1991, p. A44) argued that although educators have long purported that "Every student is capable of learning," only recently have we begun to acknowledge that students learn in different ways. The acknowledgment of learner diversity and student empowerment are the underlying themes of learning styles research. Schroeder (1993) stressed that for years, as faculty, we have espoused the common belief that students learn and develop through exposure to content. He further stressed that we have been accustomed to a traditional learning process where "... the one who knows (the teacher) presents ideas to one who does not (student)" (p. 22). Cavanaugh, a high school principal in Worthington, Ohio noted "Too many teachers are like a doctor who sticks his head into a full waiting room and says, 'All of you take two aspirin and come back tomorrow.' That's educational malpractice, because it doesn't fashion a remedy for a specific need" ("Students Learn." 1979/1980). Marshall (1990) stated "We will continue to be in 'systems failure' as long as we resist the concept of the dignity and value of each individual that such a philosophy [i.e. learning styles] celebrates" (p. 62).

Guild and Garger (1985) have argued from their own experiences in studying and applying research on learning styles that "... style is the most important concept to demand attention in education in many years. Style is at the core of what it means to be a person" (p. viii). These researchers debated that style is an age-old concept that has only recently been infused with new energy and direction in education. Furthermore understanding style, they stressed, is essential to *any* educator's philosophy of education and it clearly affects how we view our educational system as a whole.

Sternburg (1990) indicated that any subject can be taught in a way that is compatible with any style. As a result he said "... students will seek learning activities that are compatible with their preferred styles - just as teachers will tend to teach in ways that are compatible with their own styles" (p. 368). Sternburg noted that no one relies on a single style. However, he stressed that some individuals are more flexible in shifting from one style to another. Sternburg maintained that teachers who adhere rigidly to a single teaching style will almost never reach a majority of their students because they are too tightly locked into what worked for them. He also noted that some students are more flexible than others in terms of their ability to switch from one style to another. Because teaching every student through his/her own preferred style would be difficult, a teacher's goal should not be to match strictly teaching style to student learning style, but to use students' preferred style as a point of entry. Students need to be assisted in developing ways to capitalize on their own learning strengths, while at the same time, work toward developing the ability to move from one style to another.

Rather than assuming knowledge about students' learning styles, they should be formally assessed. Flaherty (1992) earlier made this contention and maintained that the first step is to see students through their assets rather than their liabilities. Results of these learning style assessments can be effectively utilized to modify instruction.

Hand (1990) asserted that she doesn't emphasize diagnosis when she assesses students' learning styles. Rather, she uses the assessments to help students become more aware of their own learning styles so they can develop their own strategies "... for dealing with the diverse demands of school and of life in general" (p. 13). She suggested that focusing on learning styles can benefit students by giving them confidence in their strengths and opportunities to develop diverse strategies for coping with challenging learning situations which inevitably arise. These benefits, as noted by Hand, encourage students to take responsibility for their own learning.

Conceptual Understanding in Kinematics - Graphical Construction

Conceptual change as it relates to student learning of kinematics has been studied extensively. Trowbridge (1979) noted several areas of difficulty that students have in learning basic kinematics concepts. He interviewed over 300 with introductory physics students by allowing them to view the real motion of objects and then asking them to describe and interpret that motion in their own words. In these interviews students were assigned various *speed comparison tasks* in which they were to observe and describe the motion of actual objects (Trowbridge & McDermott, 1980). Many students were not able to discriminate clearly between position and velocity. This inability to discriminate between position and velocity was especially apparent when students were confronted with the actual motions of objects. Further, these investigators found that students were unable to discriminate between position and velocity even after a considerable amount of formal instruction in kinematics (Trowbridge & McDermott, 1981). They also found evidence that students' preconceptions regarding their interpretations of motion in the real world were very "persistent." Results of pre- and post-course interviews indicated that students appeared to maintain their confusion regarding speed and position.

In the same study Trowbridge and McDermott looked at student understanding of the concept of acceleration with a focus on students' qualitative understanding of acceleration as the ratio $\Delta v/\Delta t$. An example of student difficulties with this concept comes from interviews in which students observed a ball as it rolled to the top of an inclined track, changed direction and rolled back down. Some students stated that the acceleration was zero at the top of the incline. They believed that, when the direction of motion of the ball changed, the direction of the acceleration changed and, thus, it had to pass through zero. Results further indicated that about one-third of students interviewed continued to have difficulty with acceleration that remains constant when the velocity does not. Their results indicated a need to continue to analyze and understand student thinking and learning processes of basic kinematics concepts. The current study revisited some of these same issues through the lens of student graph construction and interpretation after laboratory instruction that utilized interactive digital video techniques.

Building upon the work of Trowbridge and McDermott, Rosenquist and McDermott (1987) focused on three key elements in the development of a conceptual approach to teaching kinematics. The first element consisted of developing a qualitative understanding of instantaneous velocity as a limit by utilizing student direct observation of motion. The goal was to facilitate students' ability to recognize key features of definitions, distinguish related concepts from one another, and make explicit connections among concepts, their graphical representations, and the real world. The second element was the development of techniques to aid students in distinguishing the concepts of position, velocity, change of velocity, and acceleration from one another. The third element involved the design of strategies and instructional materials to aid students in making connections among the various kinematical concepts. their graphical representations. and the motions of real objects. To make these connections. students were asked to construct graphs following the observation of the actual motions of objects. In addition, students were asked to look at a graph and then produce motions that would parallel the graphical representation. Here. Rosenquist and McDermott suggested that having students reason in both directions (i.e. from real motion to graphical representation and from graphical representation to real motion) actually allows them to relate better the characteristics of an actual motion to the graphical representation.

McDermott, Rosenquist and van Zee (1987) looked at difficulties that students have in making connections between graphs and physical concepts and in making connections between graphs and the real world. The difficulties described by these researchers included

- discrimination between the slope and height of a graph.
- interpretation of changes in height and changes in slope,
- relating one type of graph to another,
- matching narrative information with relevant features of a graph, and.
- interpreting the area under a graph. (p. 504 - 506)

Looking at each of these difficulties they suggested that "A realistic assessment of student ability to extract information from a graph must therefore involve elements of interpretation ..." (p. 507).

McDermott. Rosenquist and van Zee have also described students' difficulties when they make an attempt to relate a graph to a particular object or real world event. They asked students to view the motion of a steel ball released from a starting ramp. After the ball rolled along various combinations of straight tracks, students were asked to draw position- and velocity-versus-time graphs of the motions they observed. When students were asked to produce a motion that is represented pictorially on a graph, they would often arrange the tracks to look like the position- or velocity-versus-time graph they were attempting to interpret. Students would essentially interpret the graph as a photograph of the event they had observed rather that a depiction of the motion characterized by the event.

McDermott, Rosenquist and van Zee asserted these various difficulties often go unnoticed during traditional instruction. Students in traditional classrooms would most likely have the skills needed to mechanically draw a graph; however when further analysis is demanded, they may not have established a pattern to perform more detailed interpretations. Thus, these investigators indicated that an ability to reverse one's thinking from real motion to graphical representation and from a graphical representation to real motion facilitates the construction of a deeper understanding than that which is typically assessed in most traditional physics courses. As a result of their research, they designed an instructional module in kinematics (McDermott & Rosenquist, 1984). This work is now published as part of the Physics by Inquiry modules (McDermott et al., 1996).

Building upon the previous work, Grayson and McDermott (1996) conducted a study to determine whether computer-based instruction could shed some new insights into student thinking that might therefore help improve the match between teaching and learning. These researchers focused on the reasoning that students used as they attempted to resolve discrepancies between their own predictions and observations as they worked through two computer programs *Graphs and Tracks* (Trowbridge, 1989) and *Atwood* (Grayson, 1990). Of primary interest in this review is their results of students' interactions with the *Graphs and Tracks* software.

Grayson and McDermott used computer-based interviews in which students were asked to make a prediction before viewing an event as simulated by the computer. The students then compared their prediction to the actual motion event and explained any discrepancies. Students were shown three different position-versus-time graphs and asked to set up the initial conditions that would relate to each of these graphs using the tracks displayed on the computer screen. If students' predictions were incorrect, they could try again. The only stipulation was that they had to "think out loud" as they were working, thus providing the investigator a window into their thought processes.

Grayson and McDermott were able to provide some insights into how students think when confronted with something that contradicts their expectations. If students maintained a very strongly held belief, it was often difficult to get them to change it even when they were presented with contradictory evidence. Simply facilitating a situation that will force a conflict between a student's previously held belief (in this case a preconception that is incorrect) and accepted scientific models or concepts is not sufficient to bring about a resolution of the conflict. These investigators suggested that "To develop a sound understanding of physics, students need to be helped to recognize in what ways their own ideas fall short and why scientifically correct concepts are more useful" (p. 564). This invokes an old cliche' "You can lead a horse to water, but you can't make it drink." Likewise, you can present students with the *correct* answer, but you can't make them accept it.

Studies have also been conducted regarding students' graphical interpretation ability in general. Brasell (1990) spoke to the issue of experts and novices and the apparent differences in their ability to interpret graphs. She suggested that novice graphers often perceive graphs as equivalent to tables in displaying only specific data points. In addition, novice graphers often have difficulty in selecting the relevant features from a graph and are often unaware of the mathematical properties of graphs or their power to synthesize and integrate information. Brasell suggested that novice graphers typically display two kinds of problems. The first is their inability to obtain information from the slope or height of a graph, while the second is their somewhat common failure to really understand the extent of information that is available from a graph. In addition, she contended that novice graphers also have difficulty relating a graph to another representation of the same information. Items that seem to cause particular difficulty are relating one graph to another, matching verbal and graphic information, and linking graphs with real-world variables or with physical phenomena being represented.

Upon comparison of novice to expert graphers, Brasell asserted that, through practice, expert graphers are able to recognize a particular shaped graph as being representative of a whole class of events. In this way, she noted that expert graphers are able to process these features within a cluster or "chunk" of information. Furthermore, expert graphers are typically able to appreciate the functions of graphs in synthesizing and integrating information and also in summarizing data. Expert graphers are also able to perform tasks such as identifying the dependent variable and visualizing it in terms of the way it changes with respect to the independent variable. In addition, expert graphers use what Brasell referred to as "cognitive templates" to match the type of event with the shape of the associated graph, which requires higher level cognitive processing skills.

Brasell and Rowe (1993) suggested that overall, science instruction uses graphs rather sporadically and then overemphasizes just a limited range of graph formats, conceptual content, and graphing tasks. Graphing is used sporadically at all levels of introductory physics instruction, from the typical materials used in a course for non-science majors to those used in a calculus-based course for physics and engineering majors. Brasell also posited that lab manuals often just display graphs with titles, labels, and scales included. Textbooks, as well, often include graphs, but typically fail to discuss them adequately. Thus the study of motion using graphs may be treated as "superfluous adornment." Brasell asserted that students need to have an opportunity to have repeated experiences with a whole range of graphs that are used as an integral mechanism for the conveyance of information both in many courses and in many contexts.

Multimedia and Computer-based Techniques - Student Cognitive Development

The introduction of technology in our physics classrooms and laboratories can have an impact on student understanding. One of the first significant applications of computer technology in physics teaching was the computer-based laboratory. Thornton (1987) described early work with non-science majors in which students were first introduced to distance and velocity graphs by viewing the motion of their own bodies using a motion detector. As students moved, they were able to see simultaneously graphs of their motion displayed on a screen. Based on students' responses to verbal questions, discussions amongst themselves, laboratory sheets, and homework, the level of understanding of the students was judged to be quite high. In fact, Thornton revealed that the level of understanding regarding kinematics concepts was as high as that of physics majors in another class which received the traditional mathematical treatment of kinematics. Thornton described several pedagogical advantages of the use of computer-based laboratory tools. He indicated these tools:

1) enhance learning by extending the range of student investigations,
2) are usable by the novice,
3) can encourage critical thinking skills and reduce the drudgery of data collection and manipulation,
4) can encourage learning from peers,
5) may be an effective means of teaching graphing,
6) may make the 'abstract' concrete through immediate feedback,
7) can be an aid to those with science anxiety, and
8) seem especially effective for the under prepared student. (p. 235 - 237)

Although many of these points have been articulated in this literature review, the fifth point is of particular interest. Thornton suggested that even physics majors who have the ability to understand and construct graphs, often are not able to make the connection between the information conveyed on a graph and some type of real world action that might have produced the graph. Later Thornton and Sokoloff (1990) concluded that even though preliminary evidence suggested that using computer-based laboratory tools leads to increased student interest, such activities still do not necessarily improve student understanding of fundamental kinematics concepts. These researchers suggested that computer-based laboratories, when used in conjunction with appropriate curricular materials, can lead to gains in students' learning of physics concepts. The curriculum is the guide for the overall process of learning as more applications of computer-based laboratory techniques are developed and utilized.

One example of a computer-based laboratory tool is a motion detector which was developed using a sonic transducer. The probe is a SONAR unit that transmits high frequency sound (50kHz) and then detects and amplifies the echo. A computer is used to measure the time between the transmitted and the received pulse. Thus, the position, velocity and acceleration of an object can be determined. Further, any (or all) of these quantities can be displayed on a screen at a given time. Thornton (1987) offered that these computer-based laboratory tools "... make an understanding of physical phenomena more accessible to the naive science learner and expand the investigations that more advanced students can undertake" (p. 232).

Referring to the rapid changes in technology over the past few decades, Fuller (1993) used the term "hypermedia" to describe the extension of "hypertext" (a term coined in the 1960's by Theodor H. Nelson to mean nonlinear or non-sequential reading and writing). Hypermedia, Fuller said "... is the extension of hypertext to include graphics, video, animation, and sound" (p. 300). Fuller suggested "The primary task of hypermedia in the knowing of physics is to facilitate these on-going changes in the mental processes of students as these processes are related to concepts in physics. What we need to do with hypermedia is not make physics easy, but to make it slightly complicated. Thus the hypermedia task is to provide a credible reality and a challenge to existing mental processes of the students, in short, to provoke them into an appropriate level of cognitive conflict" (p. 301). Note however, that students must wrestle with the material on their own, molding it and shaping it to fit into their existing cognitive schema. Lamb (1992) suggested that the combination of multimedia and hypermedia can be used to make learning an active process.

The potential learning applications for multimedia technology are virtually endless at this point. Ultimately, a goal of using multimedia instructional techniques is to provide for enhanced understanding and higher motivation toward the learning of the physics concepts taught. Dede (1992) suggested that various multimedia tools offer great potential to empower learners' mastery of higher-order thinking skills. Dede further noted that the leverage multimedia techniques provide stems from a synthesis of multiple attributes rather than from any single characteristic. These attributes include: learning via structured discovery; motivational power; ability to tap multiple learning styles; web-like presentations of knowledge; enhanced mastery through learner authoring of materials; the collection of rich evaluative information; and, technology-supported collaborative inquiry. The wide-spread and ever growing availability of technology developed for instructional purposes is almost overwhelming. We need to take a long, hard look at the question of how technology can be best utilized to enhance the teaching and learning process.

The overriding issue, according to Laws (1988) is "... not simply what to teach, but how to teach" (p. 23). She noted that an "endless array" of new computer-based instructional media currently exists. In addition, Laws further indicated that we have developed new understandings about student pre-conceptions and naive problem-solving strategies. The embodiment of this new "instructional technology" as Laws suggested is being translated into classroom applications of these new understandings about the learning process. We need to focus on the implication(s) that these new technologies have for impacting the overall learning process.

In their study of the impact that technology, particularly interactive video, may potentially have on at-risk students, Kozma and Croninger (1992) made use of current evidence from cognitive psychology. This evidence suggested that learning is an active process by which learners manage their available cognitive resources while working to construct and process new knowledge. These investigators highlighted that learning with media can be viewed as a complementary process within which representations are constructed and procedures performed, sometimes by the learner and sometimes by the medium. Moreover, video can be used to link current mental representations of concepts to real world situations in a way that learners with little prior knowledge may have trouble accomplishing on their own. Hamming (1996) further suggested that interactive video when used in conjunction with more traditional educational techniques like lectures and physical lab work, can lead to "... significant levels of understanding and awareness ... with increased retention" (p. 15). The design of assessment techniques to substantiate Hamming's claim here, as well as those made by others, are certainly needed. Moreover, Wills and McNaught (1996) urged researchers to question how assessment procedures are designed to provide information about students' learning.

The educational benefit(s) that new technologies, such as interactive video, may have for students is of continued interest to study. However, Cronin and Cronin (1992) suggested that a theoretical framework specific to interactive video instruction has yet to be developed. These authors also noted that theories adapted from various other forms of multimedia instruction have failed to identify the unique pedagogical attributes of interactive video instruction. Cronin and Cronin presented a synthesis of research that focused on interactivity, visuals, motivation, and learner control in interactive video instruction. Regarding learner control and interactive video instruction, these researchers stated that "The capability of IVI [interactive video instruction] to adapt to various learning styles and provide for learner control also has been invoked to explain educational outcomes" (p. 38). These researchers argued, however, that the unique advantages of this type of instruction in providing for learner control and allowing adaptation to learning style have not yet been identified. A need remains to assess the role that these multimedia tools, such as interactive video, play in terms of promoting deeper learning, possibly for students with particular types of learning styles.

The development of various multimedia learning tools has spurred a movement away from learning which is teacher-centered and teacher-directed to one which is centered on the learner. Zollman (1996) stated that "... technology can be most valuable when it helps move toward student-centered learning" (p. 116). One desirable outcome of this movement toward a student-centered learning approach is increased motivation toward learning on the part of the students. An example of a more student-centered approach is the capturing of digital video by students themselves. Capturing their own data using a video camera would seem to give students more control over the learning situation.

Multimedia and Computer-based Techniques in Relation to Kinematics Graphs

Of particular interest in this study was interactive digital video technology and the role(s) it may play in terms of facilitating student understanding of basic kinematics graphs. To date, only a few studies have been geared to assess the impact of interactive digital video (or other multimedia) techniques on student conceptual development of kinematics concepts. Regan and Sheppard (1996) stated that within the growing volume of engineering multimedia courseware "... there is generally a dearth of formal studies to assess whether multimedia facilitates enhanced/improved student learning" (p. 123). Although their research focused on multimedia courseware for teaching engineering students, certainly one can make a similar argument for multimedia courseware for teaching physics students.

Brasell (1987) used the sonic ranger device described earlier by Thornton (1987) to look at real-time graphing (where the graph is displayed simultaneously with the motion of an object) and compared it to delayed-time graphing (where the graph is produced a short period after the motion has taken place) in terms of students' ability to improve their comprehension of distance and velocity graphs. The real-time graphing techniques thus provided for simultaneous, rather than sequential processing of a motion event. The real-time students saw graphical displays simultaneously with their motions, while the delay-time students saw the graphical displays approximately 20 seconds after their motion was completed.

Brasell stressed that novices are especially prone to what she calls "cognitive overload" because they are not sure of the salient features of an event when they are observing it. She asserted that movement in a display dominates an individual's attention and therefore may encourage students to selectively focus on the more pertinent features of a graph (such as changes in speed or direction). Brasell also noted that the real-time feature of computer-based labs is not their only attribute. She posited that computer-based laboratory activities allow a student to repeat an activity a large number of times and gives them plenty of opportunity with graphing events. This repetition should serve to reinforce concepts and allow students to pick out salient events.

An interesting result of Brasell's work showed that students in the delay-time group displayed less improvement in their graphing skills when compared to students who saw a real-time display. She presented three possible reasons for this result. First, the tasks themselves surpassed the students' memory capacity. Second, students may not have been motivated enough to expend the effort needed to perform the tasks.

Finally, students simply did not know how to retain the information about the event in their minds until the time the motion was displayed. She also noted the delay-time groups seemed to be less actively engaged in what they were doing. Furthermore, she noted that these students seemed to focus on procedural rather than conceptual issues. Brasell's research indicates that computer-based laboratory activities do hold "pedagogical promise" for learning science concepts and associated graphing skills.

Following the work of Brasell, Beichner (1990) used real-time computer-based experiments to allow students the opportunity to visualize as well as feel the connection between a physical event and the corresponding graphical presentation. The students in Beichner's study were divided into two groups; a traditional group and a VideoGraph group. All students were involved with the analysis of the motion of a projectile. Students in the VideoGraph group viewed the replay of motion events in the form of computer animation of videotaped images. Beichner indicated that the major difference between the two groups was that "... the traditional groups had to produce their own data tables, construct graphs, and then calculate slopes and areas by themselves. For the most part, these tasks were done automatically for the VideoGraph groups..." (p. 807).

Beichner was interested in learning whether groups that used the computer to simultaneously view the motion of images and related graphs would show a higher mean score on a kinematics graph interpretation test than students who used more traditional techniques. His assessment tool was the Test of Understanding Graphs-Kinematics (Beichner, 1994), which was also utilized in the current study and is described in the following section. Beichner was also interested in determining whether students who had viewed the motion events would score significantly higher on the test than those who had not. He looked at interaction effects comparing mean scores for students in the traditional groups (showing differences between viewing or not viewing the motion event) to mean scores for students in the VideoGraph groups. In addition, Beichner looked at differences between pre- and post- test scores to determine whether learning had occurred.

Results of Beichner's analysis did show that students in the VideoGraph groups had higher scores than those in the traditional groups; however the difference was not large enough to be statistically significant. Furthermore. Beichner did not find any significant difference between groups who had witnessed the motion event and those who had not. He suggested that this finding may be a result of students' observations of a simple motion. Beichner further suggested students might have a significant advantage witnessing the event if the motion were complex and unfamiliar. Pre- and post- test gains for students in the traditional groups were sizable. Beichner suggested that these students may have been more heavily involved with their data than students in the VideoGraph group. Beichner concluded that in a single-exposure situation, working with a simulation is no better or worse than traditional lab experience.

Research conducted by Brungardt and Zollman (1995) also followed that of Brasell. Brungardt and Zollman looked at student analysis of videodisc-recorded images with treatments over an extended period of time. Students viewed various scenes from the *Physics of Sports* videodisc (Noble & Zollman, 1988). To collect data students would mark the position of the object on an acetate attached to the screen, advance the videodisc a couple of frames, and mark the object's position again. Students could scale their data by placing the acetate screen on top of a piece of graph paper and then enter it into a spreadsheet. Software allowed students to calculate velocity and acceleration data and display graphs of kinematics variables versus time on the computer screen.

Brungardt and Zollman utilized two treatment groups: a simultaneous-time group and a delayed-time group. The students in the simultaneous-time group viewed the kinematics graphs on the computer screen simultaneously with the videodisc-recorded motion of the object on the video screen. The delayed-time students viewed the motion of the object on the screen and then, after a period of several minutes, viewed the corresponding kinematics graphs on the computer screen. These researchers made use of a post-test only, contrast group design in their investigation. The post-test used was the *Questions on Linear Motion* section of the test for *Tools for Scientific Thinking* (Center for Science and Mathematics Teaching, 1988). Results of their investigation showed that scores for students in the simultaneous-time group were higher than scores for students in the delayed-time group; however, the difference was not statistically significant. This result suggests that the simultaneous viewing of kinematics graphs along with the corresponding motion of an object on a video screen may lead to enhanced student understanding.

Brungardt and Zollman also analyzed qualitative data obtained from interviews with students. They observed ten recurring themes which emerged from analysis of the interviews, noting that categorization of student comments into themes is somewhat subjective. Examples of emergent themes included: differences between simultaneous-time and delayed-time groups, graphs as a picture error, and use of vocabulary. Brungardt and Zollman concluded that the "... simultaneous-time effect is not a critical factor, in and of itself, of improved learning of kinematics graphing, although it may have advantages in some other areas. The question remains as to why the MBL [microcomputer-based laboratory] curricula are relatively successful. Further studies may investigate the kinesthetic nature of MBL tools, or other factors such as the ability of MBL tools to produce many graphs per time" (p. 867).

Chaudhury and Zollman (1994) discussed using digital video techniques to help students understand the concept of frames of reference. Students recorded video of a ball being dropped in four different reference frames. In their analyses, students stepped their own video forward a frame at a time and marked the position of the ball with a mouse-pointer. A graph of height above ground versus frame number was then generated as students continued to mark the position of the ball. Students were given pre- and post- tests regarding their conceptions of relative motions in various reference frames. These investigators concluded that the capabilities of interactive digital video can have an important contribution to the teaching of physics.

Using video analysis tools which they had developed and modified, Escalada, Grabhorn and Zollman (1996) described five different lab activities which focus on investigation and inquiry. Within these activities, students captured their own video and performed their analyses using one of the computer programs designed to analyze the motion of objects. In addition, students completed various instructional activities. The two interactive computer programs that were utilized in their study were *Video Analyzer* and *Visual Space-Time.* The *Video Analyzer* program allowed students to capture and play an image and then collect position-time data from it. The *Visual Space-Time* program permitted the combination of video frames and the automatic detection of the locations of objects in successive frames. In addition, *The Visual Space-Time* program allowed playback of scenes from reference frames that were different from the ones in which they were recorded.

Escalada, Grabhorn and Zollman expressed that these interactive tools were developed to facilitate the movement of students' conceptual development from the concrete to the abstract. These researchers maintained that "By utilizing real-life, story-line scenarios with the appropriate equipment and materials to model these problems, thought-provoking questions to facilitate meaningful learning, and user friendly video to provide powerful visualization experiences, the digital video activities and tools can be used by students to make connections between concrete, real-life phenomena and the abstract ideas and models of physics" (p. 17). Lloyd (1991) asserted that perhaps the major role of classroom computers is to allow students and teachers to work in ways that are not possible with conventional means of instruction. Practical examples (such as those described using digital video techniques) of abstract concepts can be presented over and over again, in endless combinations.

Description of the Test of Understanding Graphs-Kinematics (TUG-K)

The Test of Understanding Graphs-Kinematics (Beichner, 1994) can be used to help physics teachers and researchers examine what students are learning about the topic of motion via their interpretations of kinematics graphs. This test consists of 21 multiple-choice questions with three questions for each of seven main objectives. These objectives are:

1) Given a position-versus-time graph the student will determine velocity.
2) Given a velocity-versus-time graph the student will determine acceleration.
3) Given a velocity-versus-time graph the student will determine displacement.
4) Given an acceleration-versus-time graph the student will determine change in velocity.
5) Given a kinematics graph the student will select another corresponding graph.
6) Given a kinematics graph the student will select textual description.
7) Given a textual motion description the student will select a corresponding graph.

Beichner refined this instrument by first administering draft versions of the test to various groups of students. Draft versions of the test were administered to 134 community college students (who had already studied kinematics concepts in class). The test was then revised again and given to 15 science educators (ranging from high school to college teachers). These educators were specifically asked to criticize the items and comment on the appropriateness of the objectives. This procedure determined the content validity of the items.

The Test of Understanding Graphs-Kinematics was then administered by Beichner as a pre-test to 165 high school juniors and seniors from three different schools as well as 57 students from a four-year college physics class. Every student tested had already been exposed to traditional kinematics instruction. These students were randomly assigned to one of four different 2-hour laboratory activities. The same group of students then took an alternate version of the test. The Pearson product-moment correlation between pre- and post- test scores was 0.79. This result provided evidence that the two versions of the test examined similar knowledge constructs. Further, a paired samples t-test showed a significant increase in the mean scores between pre- and post- lab testing [$\underline{t}(221) = 4.864$, $\underline{p} < .01$]. Beichner reported that this increase in mean scores was evidence of the validity of the instrument. Further refinement led Beichner to develop a final version of the test which was used in the current investigation.

The final version of the Test of Understanding Graphs-Kinematics was given to 524 high school and college students from around the country. The mean score on the test was 40%, which was quite low considering the test was administered after students had received traditional instruction in kinematics. Using the Kuder-Richardson formula (KR-20) Beichner reported a reliability for the test of 0.83. A point-biserial coefficient averaged over the individual test items was 0.74. A point-biserial coefficient of 0.20 is normally considered sufficient. In terms of item discrimination indices, a Ferguson's delta value of 0.98 was determined with a value of 0.70 usually an acceptable minimum. Beichner reported that these statistics indicated that the Test of Understanding Graphs-Kinematics is useful for diagnostic purposes and should be a helpful research tool.

Beichner performed additional analyses on the test results of the 524 students who took the final version of the test. Beichner reported a mean score of 9.8 overall for students taking a calculus-based physics course and a mean score of 7.4 overall for students taking a trigonometry-based physics course [$\underline{t}(335) = 4.87$, $\underline{p} < .01$]. Students in Beichner's study had not received special instructional treatments, but had received kinematics instruction at some time during the course. He further concluded that because the test scores were relatively low (around 40%), students definitely had trouble interpreting kinematics graphs. Beichner also noted that college students did not score significantly better than the high school students who took the test. He reported a mean score of 9.1 for college students and 8.3 for high school students [$t(522) = 1.50, p < .13$].

Upon further analysis Beichner reported a mean score of 9.5 for males and 7.2 for females who took the test [$t(491) = 5.66, p < .01$]. This difference in mean scores is statistically significant. Furthermore, because of this reported difference in mean scores on the Test of Understanding Graphs-Kinematics between males and females, gender was included as an independent variable in the statistical model developed for use in the current study.

In a later study, Beichner (1996) administered the Test of Understanding Graphs-Kinematics to five different groups of students, each receiving various levels of multimedia instruction in kinematics and graphing. *VideoGraph* (Beichner, 1995) was used by the five teachers (Teachers A - E) participating in his study. The first group of students were instructed at a science magnet school and were taught by Teacher A. Teacher A's students had extensive exposure to learning kinematics using video software. Further, this teacher had the opportunity to work with the video software for two academic years, so was able to benefit from her extensive work with the instructional software. Beichner reported a mean score of 14.3 ± 0.4 (after the first year of video labs) and 15.5 ± 0.5 (after the second year of video labs) for students in Teacher A's class.

Teacher B was Beichner himself. He used video analysis demonstrations with his college-level class, but no laboratory activities were conducted. A mean score of 12.9 ± 0.8 was reported for this group of students. Other college classes were taught in a large lecture format. The students were divided into smaller lab sections taught by various teaching assistants, who where collectively labeled Teacher C. Some sections of students in these classes performed three detailed video labs. but were not exposed to video during lecture. A mean score of 12.1 ± 1.1 for these students.

Teacher D taught at the same science magnet school as Teacher A. Teacher D's students were exposed to brief video labs and had a limited amount of exposure to video demonstrations during lecture. A mean score of 10.8 ± 1.1 was reported for these students. Teacher E instructed students at a suburban high school and had limited computer resources. The instructor was able to demonstrate some motion concepts using an Apple II microcomputer and an ultrasonic range finder. Using borrowed computer equipment, this teacher was able to use the *VideoGraph* software in his classes just once. Furthermore, students in this group were exposed to traditional instruction in kinematics prior to the use of the video analysis software. Beichner reported a mean score of 9.8 ± 0.6 for students in Teacher E's class.

Finally, some of the lab sections in Teacher C's classes received no video analysis and did no video labs. When scores for these students were combined with students in Teacher E's classes who had also not performed any video labs or done any video analysis themselves, a mean score of 10.1 ± 0.5 was obtained. Overall, these five groups represent a hierarchy of levels of exposure to video analysis software. Beichner's results suggested that the greater level of exposure to video analysis software tools, the higher the mean scores on the Test of Understanding Graphs-Kinematics. Further study to investigate the significance of this claim is warranted. In addition, Beichner also noted that to assess effectively various types of instructional technology teachers must thoroughly integrate the software into their instruction, rather than just tack it on somewhere.

Learning Styles - Links to Physics and Multimedia/Computer-based Instruction

Although links between multimedia and diversity of learning styles have been discussed, no studies have been conducted to date which formally assess students' learning styles and their connections to students using multimedia techniques to learn kinematics concepts in physics. The current study addressed precisely these issues.

Using computers and other multimedia tools in the classroom and laboratory may increase the potential for educators to appeal to a broader range of student learning styles. Weiss (1994) noted that introducing technology into the learning environment "... has been shown to make learning more student-centered, to encourage cooperative learning, to improve students' self-concept and attitudes toward learning, and to stimulate increased teacher/student interaction" (p. 30).

The issue of how and what we teach is particularly intriguing in light of all the new multimedia technologies now available. Mokros and Tinker (1987) highlighted one reason that computer-based laboratory techniques are such a powerful tool for teaching graphing techniques is that they use multiple modalities. These researchers suggested that in working with computer-based laboratory techniques students have the kinesthetic experience of manipulating the lab materials. Furthermore, sometimes students even have the opportunity to analyze their own motion. The kinesthetic experience is reinforced using computer-based techniques via various forms of visual stimuli. Sometimes a computer-based laboratory activity even has an auditory component. This multimodal approach to learning styles, according to Mokros and Tinker "... enables students to use their 'strong' intelligences or learning styles and at the same time encourages them to build upon learning modalities that are weak" (p. 381). Krajcik, Simmons & Lunetta (1988) called attention to the interaction between student learning styles and mode of presentation in terms of their influence on student behaviors.

Zollman (1996) discussed the importance of information technologies and their ability to provide "learning paths" for more individualized learning opportunities for students. Zollman suggested "When a large quantity of learning material is available, the selections which one student uses for learning physics could be quite different from all of his/her colleagues. Each can find in the collection of information a match with his/her own needs, styles, and background" (p. 116). He further stressed that in order for these types of capabilities to become a reality, students must have various ways to be able to search through and organize substantial amounts of information. One tool Zollman suggested for this purpose is the *Physics InfoMall* (Zollman & Fuller, 1994). The *Physics InfoMall* is designed to be like a shopping mall for physics resources and includes several textbooks and thousands of articles. This shopping mall approach gives students many choices, which permits them to choose and create their own "learning paths." Zollman noted a potential "trap" to this approach. "The hard question is: Can we expect students who clearly are not very aware of their own learning styles to develop, from a vast amount of information and resources, their own learning paths" (p. 116)? Zollman responded to his question by saying that at the present time the answer would probably be "No." He further suggested that "Part of our job as teachers will become teaching students how to work with vast amounts of information, just as our job now includes helping students' intellectual development" (p. 116). I would like to add to Zollman's suggestion that part of our role as teachers should be to facilitate students' understanding of their own individual learning styles to aid them in the development of their unique "learning paths."

After conducting a study to assess the possible interactions between learning styles and learner control treatments using an interactive videodisc lesson, Burwell (1991) concluded that the need exists to investigate particular circumstances under which visual information may either assist or distract learning in regard to differences in learning styles. Further, he suggested this need is heightened as the use of information-rich, computer-delivered instruction grows.

With the development of multimedia tools such as digital video comes the need for their assessment in terms of learning outcomes. In addition, an area warranting further study is student learning styles and the role(s) they play in student learning of basic physics concepts using these relatively new tools. Dede (1992) suggested that multimedia can reach a broader range of student learning styles than any single medium. For example, digital video techniques rely heavily on students' visualization abilities. A pertinent question then would be to look at whether students whose instruction includes digital video techniques and whose learning styles include a strength in the visual modality would have greater learning gains on an appropriate assessment measure than students who did not.

Zollman (1997) suggested that video in a variety of forms (e.g. videotape, videodisc, and digital video) offers students a way to begin their learning path via the visualization of a familiar, as well as concrete event. Thus visualization is the channel through which students will hopefully move from concrete thought to more abstract conceptualizations. Zollman added that "... by analyzing these events through modeling and digitalization students can explore real-world events through hands-on experiences and see how physicists use abstract mathematical and visual models to understand nature better" (p. 7).

In his research, Zollman described an activity in which students viewed a collision from a videodisc between a car and a wall and then collected data for analysis of the observed motion. Zollman and Fuller (1994) also indicated that showing students scenes from a video of some type of motion event *before* actual instruction takes place can lead to enhanced student motivation. Furthermore, these investigators suggested that digital video techniques, often called "synthetic video processing," permit students a visual means to answer "what if ..." kinds of questions. In addition, digital video techniques may facilitate the movement of students from their own concrete experiences to more abstract conceptions. These techniques should be particularly valuable for students who prefer visual approaches to learning.

In addition to the visual element available with digital video techniques, a tactile or "hands-on" element is also present. In addition to handling equipment, students are also interacting with a computer. An interesting question is whether students whose learning styles show a tactile strength will have more positive learning outcomes when instructed using such techniques.

In addition to the visual and tactile elements, a kinesthetic or movement element is also involved when using digital video techniques in a laboratory setting. Students are moving and collecting their own data (which is often a digitized video clip of themselves or a partner). Workshop Physics (Laws, 1991b) is an exemplary model of a program that provides students a kinesthetic experience by enabling students to experience forces and motions using their own bodies. The kinesthetic activity uses an apparatus that consists of two carts (upper and lower) supported by in-line roller skate wheels. Using these carts students performed various investigations of Newton's Laws. Pfister and Laws (1995) contended that when kinesthetic experiences are incorporated into a curriculum they will be helpful in eliminating some of the "traditional student misconceptions" (i.e. ones derived from "common-sense conceptions" of everyday phenomena). They reported "Although we know of no formal studies on the impact of kinesthetic apparatus on physics learning, instructors who have used such apparatus believe that the experiences are memorable, and influential in helping students to relate natural phenomena to the laws of physics" (p. 214).

Beichner (1990) looked at the kinesthetic aspect of multimedia techniques in a comparison study he performed regarding computer-based laboratory and video techniques. The purported positive effects of computer-based laboratory techniques on student learning have already been described in this document. He suggested that although there certainly is a visual aspect to the real-time computer-based labs. the visual juxtaposition (i.e. seeing the actual motion and its corresponding graph simultaneously) is not the relevant variable producing the educational impact.

Having immediate control of the physical event itself and its graphical representation might be a factor in the effectiveness of computer-based laboratory techniques for students. With these techniques students are able to get immediate feedback which tends to appeal to the visual and kinesthetic senses. Beichner reported "The kinesthetic sense is a strong one and appears to make a difference in kinematics MBL's [microcomputer-based labs]. Perhaps other areas of student investigation would not have as great a requirement for real-time data collection and display" (p. 813). Further, in the case of kinesthetic labs, the kinesthetic feedback could actually be the most important part of the overall computer-based laboratory experience.

In her work addressing the influence that learning styles have on program design in interactive multimedia, Carlson (1991) indicated that attempting to evaluate the particular effectiveness of various technologies presents certain difficulties that are not necessarily easily solved. She posited that small variations in isolated parts of a system being evaluated can be manipulated and carefully controlled in the laboratory using small numbers of students. Furthermore, this evaluation can be done in conformance with guidelines for scientific rigor. Results of such evaluations are not always generalizable to the larger world. On the other hand, Carlson asserted, entire instructional systems can be evaluated in real-life settings. In these studies, rigor is often sacrificed for wider external applicability. She argued that to expand the research related to interactive multimedia, "... it is necessary to consider factors that might influence learning, such as the design of instruction, the format for learning, and the match of learning style to instruction" (p. 42).

Summary

In this chapter a review of relevant literature regarding student learning of kinematics concepts was presented. Following this discussion, a summary of literature on conceptual change and its role in physics teaching and learning was presented. Implications for physics teaching that stem from various conditions for successful learning were also presented and discussed.

The processes by which an individual learns and retains information is one that has been carefully studied. A summary of related research was presented in the section on student cognition and learning in kinematics. This section was followed by a discussion of student conceptual understanding in kinematics. The primary focus here was to present relevant research in the area of student understanding of the construction and interpretation of kinematics graphs.

Literature related to the understanding and assessment of individual learning styles was also summarized. The issue of learning styles is one that has received a great deal of attention in recent years, yet no formal studies have been undertaken that would attempt to uncover the role(s) that learning style plays in the development of students' conceptual understanding in physics.

I contend that there is a need for research that includes a formal assessment of student learning styles to more effectively determine whether certain types of instruction (particularly interactive digital video instruction) lead to larger learning gains than do more traditional types of instruction. Furthermore, if certain types of instruction, particularly multimedia instruction, are found to be beneficial we need to ask whether all students will benefit from its implementation, or just those students who have particular learning style preferences.

The final sections of this chapter focused on a discussion of student understanding of basic kinematics graphs and the impact that multimedia and computer-based techniques have on student cognitive development. Of primary interest is the role that interactive digital video has played thus far in shaping physics instruction.

This study aimed, in part, to build and enhance the body of literature that currently exists in the area of student understanding of kinematics concepts. This building and enhancement was done via a comparison of student kinematics understanding following laboratory instruction which utilized interactive digital video as well as traditional techniques. A particular focus was on student ability to interpret motion graphs. Finally, the role that assessment of learning style plays in terms of understanding whether instruction utilizing interactive digital video techniques results in significant learning gains was investigated.

CHAPTER THREE

METHODOLOGY

This chapter presents the research design, as well as the procedures and methods of data analyses employed in this study and is divided into four sections: Research Design, Preliminary Study, Procedures for the Study, and Data Analysis. The section on research design includes a statement of the purpose of this study, the experimental design to be used, the variables to be studied, and the research hypotheses and questions to be investigated. This research study was initiated while the investigator was teaching at South Dakota State University. During the development of this study, the investigator accepted a Physics Education position at American University in Washington, D.C. The students who participated in this study are those enrolled in the *Physics of the Modern World* class at American University during the fall semester of 1996. A brief discussion regarding the background of the students who typically enroll in this course is included in the section on research design. A brief synopsis of a preliminary study at South Dakota State University is then presented. The section on procedures for the study includes information regarding selection of subjects, development of instructional materials, and a description of instruments and procedures proposed for use in data collection. The final sections outline the methods of data analysis.

Research Design

Purpose

This study was conducted to investigate students' understanding of basic kinematics concepts with an emphasis on using graphical methods after laboratory instruction that included both traditional and multimedia techniques. This study further attempted to uncover the value of using multimedia techniques to enhance and promote students' deeper understanding of basic kinematics concepts. Building upon existing research the developed strategy allowed the researcher to look at both qualitative and quantitative measures of student understanding of these concepts.

The multimedia tool of interest is interactive digital video. As noted in the literature review, many physics educators have remarked on the apparent value of interactive video and other multimedia tools to accommodate a wider range of student learning styles. However, formal assessments of student learning styles as they relate to student learning of kinematics concepts have not been reported within the body of physics education research. Of significant interest here was exploring the relationship that learning style may have in regard to student ability to interpret motion graphs when laboratory instruction included interactive digital video techniques for some students. This study represents the first in the area of physics education research to include a formal assessment of student learning styles.

Course Description and Background of Students Enrolled

The introductory course for non-science majors at American University in Washington, D.C., is a fairly traditional one-semester, algebra-based course and is entitled *Physics for the Modern World.* Most students are required to complete a one-semester college algebra course before enrolling as this course does include a problem solving component. In addition, the course also contains a strong conceptual component. Approximately 10% of the students enrolled in the course score high enough on a mathematics assessment test administered by American University that they are exempted from this algebra requirement (R. Kay, personal communication, June 6, 1996).

One section of *Physics for the Modern World* was taught by this researcher during the fall semester of 1996. All students in this section were asked to participate in this study. *Physics for the Modern World*, a 3-credit course, consists of both a lecture and a laboratory component. Topics covered in the one-semester *Physics for the Modern World* curriculum included basic Kinematics, Newton's Laws, Conservation of Momentum and Energy, Rotational Motion, Fluid Mechanics, Sound, and Waves. The textbook used in the course was Physics: A World View by Kirkpatrick and Wheeler (1995).

Students met twice a week for lecture sessions which were 75 minutes long. On alternate weeks, students met for a two-hour laboratory. Thus, students performed six laboratory experiments during the semester. Approximately 120 students, with 60 students in each of two sections, enroll in the *Physics for the Modern World* course each semester.

Students who enroll in the *Physics for the Modern World* course are typically second-semester freshmen or first-semester sophomores. A small number of the students who enroll could be classified as non-traditional (R. Kay, personal communication, June 6, 1996). Many students who enroll in the course are liberal arts majors. A typical class consists of a mixture of students from the College of Arts and Sciences, the School of Public Affairs, the School of International Service, and the Kogod College of Business Administration. Students enroll in *Physics for the Modern World* to satisfy the Natural Science requirement for graduation at American University. They may satisfy this requirement with a general Physics, Chemistry, Biology, or Psychology course.

Due to the wide range of majors in the course, one could assume that the diversity of students enrolled in *Physics for the Modern World* closely parallels the diversity of students enrolled at American University. The 1995 - 1996 catalog of American University describes its student population as being "... cosmopolitan and multicultural ..." ("The American," p. 61). According to the catalog, over 1,100 students currently attend American University from more than 130 different countries. In addition, students who attend American University represent all 50 states.

Description of Teaching Style Employed

Physics for the Modern World is traditional in terms of the topics covered. However, a traditional lecture format was not used. Studies presented in Chapter 2 suggested that the most effective way to reach a large group of students in the classroom is through the use of a variety of instructional delivery strategies. Hence, the "teacher is teller, learner is passive receiver" model of instruction has long been abandoned by this researcher. Instructional strategies used throughout the class sessions included computer-based and multimedia technologies for classroom simulations, as well as demonstrations and small experiments. During some class sessions students were presented with notes so they could focus their attention on listening to the material presented. During others, students spent time working numerical and conceptual problems. Still other class sessions made use of traditional approaches as they do work well for some individuals. A high level of class participation and discussion was encouraged and obtained.

Research Hypotheses and Questions

In this study, both hypotheses and research questions were investigated. The research hypotheses are restated from Chapter 1. To address Purpose 1 the following hypotheses were formulated:

1. A significant difference will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and score on the auditory, visual, tactile, kinesthetic, motivation, and structure elements of the Productivity Environmental Preference Survey are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

2. A significant relationship will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and score on the auditory, visual, tactile, kinesthetic, motivation, and structure elements of the Productivity Environmental Preference Survey are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

To address Purpose 2 the following hypotheses were formulated:

3. A significant difference will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and course grade are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

4. A significant relationship will exist between mean scores on the Test of Understanding Graphs-Kinematics when SAT score and course grade are treated as covariates when testing

- treatment,
- gender, and
- treatment and gender interactions.

A significance level of 0.05 was adopted for decision making purposes.

Other research questions included:

1. Do students with certain learning style strengths (i.e. auditory, visual, tactile, kinesthetic, motivation or structure) as measured by the PEPS instrument respond better to laboratory instruction via interactive digital video or traditional techniques?

2. How do students' perceptions of their learning styles compare to their scores on the PEPS instrument?

3. What is the overall relationship between students' learning style strengths and instructional techniques?

4. Does instruction using interactive digital video techniques contribute to student motivation to learn physics? If so, does this enhanced motivation to learn translate into improved performance and enhanced understanding?

These research questions were addressed using quantitative as well as qualitative investigative techniques. Quantitative data were obtained from students' scores on the Test of Understanding Graphs-Kinematics and the Productivity Environmental Preference Survey. Qualitative data were obtained from observations, student writing activities, and performance on questions related to kinematics and graphing given after students had completed each of two laboratory exercises.

Preliminary Study

A preliminary study was conducted during the spring 1995 semester with students in the laboratory portion of the introductory course for non-science majors at South Dakota State University. All students (approximately 130) in seven laboratory sections participated in the activity. This study was not a complete pilot study because statistical analyses were not performed. The goal of the preliminary study was to allow the researcher to observe students as they worked with the interactive digital video technology and to make necessary modifications in the video analysis software and laboratory procedures.

Students participating in the preliminary study conducted a freefall experiment (a topic that they had studied earlier in the semester) in which the main objective was to use interactive digital video techniques to determine a value for the acceleration due to gravity. Appendix E gives a schematic of the hardware and software employed for video capture purposes. One experimental set-up for video capture was available during each laboratory period. Approximately 18 - 20 students participated in each of seven sections of the laboratory.

The goals of the preliminary study were to observe students' overall interaction with the multimedia activity and to assess the overall completeness and thoroughness of the lab procedures. The students were very motivated to perform this activity. Many students commented that they really enjoyed taking their own video data and analyzing them. My observation was that students were more motivated to repeat their analysis of the data they had collected in an attempt to get more accurate results. Many students also commented that working with the technology and analyzing the video data was interesting. Other students commented that they really enjoyed working with the computers and doing the related analyses.

The results of the preliminary study led to a modification in the screen design of the multimedia tool. The modification involved a rearrangement of items on the screen to make the tool easier to use. In addition, the menu options were simplified to reduce unnecessary distractions for the user. The written laboratory procedures were also clarified.

Procedures for the Study

Selection of Subjects

For the primary study, sixty-eight students enrolled in four laboratory sections of the *Physics for the Modern World* at American University were asked to take part. All students in these four laboratory sections were enrolled in the same lecture section which was taught by this investigator. The laboratory sections were taught by a teaching assistant. Two sections (34 students; 17 males, 17 females) of the laboratory were randomly selected to receive traditional laboratory instruction (control group). The remaining two sections (34 students; 15 males, 19 females) received laboratory instruction using interactive digital video techniques (treatment group).

Delimitation of Content and Development of Instructional Materials

Research has shown that a single application or treatment is not sufficient to produce significant improvement in student understanding. With that in mind, two kinematics laboratory experiments were developed for use in this study. One experiment involved students' determination of the acceleration due to gravity using a one-dimensional freefall technique; the other involved analysis of the motion of a projectile in two-dimensions. These experiments are entitled *The Freely Falling Body* and *Projectile Motion.*

The instructional materials intended for use in this study have been developed based on research that was described in Chapter 2. These materials will now be described.

Students who received traditional laboratory instruction performed *The Freely Falling Body* experiment using a Behr freefall apparatus. This apparatus is constructed so that a permanent record of the position of a freely falling body (in this case a small metal plumb bob) is made on a waxed paper tape. A spark timer is connected to the apparatus so that as the bob drops a tiny mark is burned on a waxed paper tape at 1/60 second intervals. Students began by taking position and time data from the paper tape. The position-time data were used to determine the average velocity of the falling object in each prescribed interval of time. Students then plotted, by hand, a graph of average velocity of the falling object versus time. From the slope of the line students were able to determine the acceleration due to gravity.

Students who received laboratory instruction using interactive digital video techniques also performed *The Freely Falling Body* experiment to determine the acceleration due to gravity. The data included a digitized video clip of themselves (or a partner) dropping a ball. Students analyzed their data by first loading their video into the VIDSHELL application. Then, they marked the position of the ball as it fell by moving the mouse-pointer on top of the video and clicking on the position of the ball in successive frames. As students marked the position of the ball, the position and time data were recorded in a data table that appeared on the computer screen. Students used these position-time data to calculate velocities of the ball at various instants of time. These velocities were entered into a template that was available as part of the interactive digital video application. Once students had completed the template, they constructed, by hand, a graph of velocity-versus-time. The slope of this drawn line should be equal to the acceleration due to gravity.

An interesting feature was available with this interactive digital video application. When students took their position-time data using the mouse-pointer and clicked on the falling ball, they were simultaneously able to view position-versus-time, velocity-versus-time, and acceleration-versus-time plots of its motion. Thus, the interactive digital video application offered students a means to see visually graphs of their own data simultaneously as they viewed the one-dimensional motion of the falling ball in their video clip. This additional visual stimulation was not available with the traditional method.

The second experiment was *Projectile Motion*. Students receiving traditional instruction performed the experiment using a specially designed projectile launcher made of PVC piping. The projectile, in this case a golf ball, was projected horizontally from a table into a target box on the floor. Students made use of the equations of motion to predict an experimental value for the horizontal range of the gun. After making this prediction, students launched their projectiles several times to determine an average experimental value for the range. Once the range had been determined, students were instructed to return to their data and use the equations of motion to determine the horizontal and vertical components of the position and the velocity of the projectile while it was in flight. After making these computations, students plotted graphs by hand of each of these variables versus time.

Students using interactive digital video in the *Projectile Motion* experiment utilized the same projectile launcher and golf ball system as those students in the traditional groups. However, they captured video of the ball as it traveled down the ramp and into the air. For data collection a strategy similar to that used for *The Freely Falling Body* experiment was employed. Students again marked the horizontal and vertical position of the ball as it traveled through the air by using the mouse-pointer to click on its position in the video. Students made use of this position data to calculate the horizontal and vertical components of the projectile's velocity while in flight. This information was again entered by the students into a template that appeared on the computer screen. From these data students drew the same graphs by hand as those students who had taken data using the traditional approach. However, students receiving instruction using interactive digital video techniques were again able to see graphs of the vertical as well as horizontal position-, velocity-, and acceleration-versus-time for the projectile plotted simultaneously as they used the mouse-pointer to mark its position in their captured video.

The Test of Understanding Graphs-Kinematics (TUG-K)

The Test of Understanding Graphs-Kinematics was administered after all students had completed the two kinematics laboratory exercises. Composite scores of the Test of Understanding Graphs-Kinematics were used in this study. Each of the 21 multiple choice questions were treated as one point on a composite score scale of the number of items correct. Thus, the highest possible score on the Test of Understanding Graphs-Kinematics was 21 points. These scores were used in the statistical analysis described later in this chapter.

The Productivity Environmental Preference Survey (PEPS)

The categories and elements of the Productivity Environmental Preference Survey were described in Chapter 2. The concept of learning style and the Productivity Environmental Preference Survey assessment tool were discussed in class before being administered to the students. The assessments were then sent to Price Systems, Inc. in Lawrence, Kansas for scoring. Once the students' scores were received, the data were entered into a computer software package designed for analysis purposes and individual profiles were prepared for each student. Once students had received their individual analysis they were invited to discuss their results with the instructor. Throughout the semester, many students engaged in one-on-one discussions with the instructor regarding learning styles. Often times these profiles were used to help students determine a prescription for how they might change their approaches to learning and improve and enhance their learning processes (and improve their performance in physics class).

The final focus of the learning style assessments was to express to the students that they do have a unique learning style and that their style is good. Students were informed that no style is bad and that no evidence suggests that one style of learning is academically superior to another. Certainly, everyone has strengths and weaknesses when it comes to learning. Students were able to uncover their strengths and weaknesses after receiving their profiles, and many worked to capitalize on their strengths over the course of the semester.

The elements of the Productivity Environmental Preference Survey of interest in this study were: auditory. visual. tactile. kinesthetic. structure and motivation. For each of these elements standardized scores (ranging from 20 to 80) were utilized in the statistical analysis. However, only scores in the high (≥ 60) and low (≤ 40) categories were utilized for comparison purposes because they represent strong learning style preferences. Comparisons of learning style preferences are of interest between students in each group and between students based on gender. Important to note is that the number of students with preferences in the high and low categories is quite small. This fact prohibited firm conclusions from being drawn between students with particular learning style preferences and their scores on the Test of Understanding Graphs-Kinematics.

Description of Written Activities Employed

Several written activities were employed to assess student understanding of kinematics concepts. These activities also provided a mechanism by which to assess student conceptions of their learning style and the connection(s) between learning style and instructional technique.

As part of the homework assignments, students were required to keep a folder. The folder kept by the students was similar to a journal. The term journal was not used to avoid confusion between the common conception of a journal, which is typically a daily or weekly log, and the true essence of the folder activities. Rather. specific writing assignments were given the students in the form of folder activities. Students would then respond to these assignments and insert their responses in their folders. In addition to the writing component involved, the folder activity provided a vehicle through which feedback could be given to the students.

The technique used to assess students' writing was unique in that they were not graded based on correct or incorrect use of physics. Students could respond to questions asked of them honestly and without fear of penalty. Through the folder activity, students were presented with questions regarding their understanding of kinematics concepts as well as their learning styles.

Students were asked to write about their learning styles before the Productivity Environmental Preference Survey was administered. This activity was designed to encourage students to begin thinking about what factors influence how they learn best. Once the Productivity Environmental Preference Survey had been administered and students had received their individual feedback profiles, another folder activity was given. In this activity, students were asked to discuss the results of their individual feedback in detail. Students were also asked to relate this feedback to their original discussion about their learning styles given in an earlier folder assignment.

One folder activity on kinematics graphical interpretation was given students prior to their receiving the laboratory treatments. The intent of this activity was to look at student difficulties and possible misconceptions regarding graphical interpretation before any treatments had been given.

Students were also asked to provide written responses to post-lab activities administered immediately following the formal laboratory sessions for the freefall and projectile motion experiments. These activities were designed to draw upon students' ability to construct and interpret motion graphs. Students were asked to respond to these questions and turn them in before they left the laboratory. The results of the post-lab activities were used to assess, in part, the effectiveness of the laboratory treatments on students' ability to construct and interpret motion graphs.

Students were also given the opportunity to respond to a laboratory questionnaire designed to address how well they liked (or did not like) the lab and what factors may have motivated them while performing the lab activities. Analysis of student responses helped to reveal some of the effects that the two types of laboratory instruction had on students' attitude and motivation toward the activities they had performed.

Data Analysis

Analysis of Students' Conceptions of Kinematics Concepts

Several measures were used to assess students' understanding of kinematics concepts. Student composite scores on the Test of Understanding Graphs-Kinematics provided one measure of their ability to understand kinematics concepts via interpretation of motion graphs. Additional measures included an analysis of student written responses to an assigned folder activity and written responses to a post-lab activity given them after they had completed each of the laboratory experiments.

Analysis of Students' Learning Styles

Student scores on the Productivity Environmental Preference Survey were used to determine individual learning styles. Students were also asked to write about their own learning styles before and after they had taken the Productivity Environmental Preference Survey and received feedback. The folder activity was used as the mechanism for data collection.

Analysis of Student Attitude and Motivation

As students worked through the laboratory activities in both the traditional and interactive digital video groups, observations were made by the researcher to note how they were interacting with the equipment and with each other. Observations were also made by the teaching assistants as well as the individual responsible for modification of the VIDSHELL tool. Student motivation toward working with the technology was also observed. Videotapes were made of students in each laboratory section as an additional mechanism through which their attitude and motivation toward performing the activities could be observed.

A classroom assessment technique (Cross and Angelo, 1993) was utilized to further analyze student motivation. This assessment was given in the form of two laboratory questionnaires. Students were asked to comment, in writing, regarding their experiences in the lab and what (if anything) they found interesting when they performed the experiments.

Statistical Analyses

Statistical procedures used to test the hypotheses involved analysis of covariance techniques (ANCOVA). The independent variables were instructional treatment (labeled treatment and control) and gender. The control group consisted of students who received traditional laboratory instruction, whereas the treatment group consisted of students who received laboratory instruction using interactive digital video techniques. The dependent variable was student composite score on the Test of Understanding Graphs-Kinematics. SAT score, course grade, and student response on the auditory, visual, tactile, kinesthetic, motivation and structure elements of the Productivity Environmental Preference Survey were treated as covariates. SAT score and course grade were treated as covariates in the analyses to adjust for potential differences in academic ability levels between groups that existed prior to the commencement of this study.

An analysis of covariance (ANCOVA), using the general linear models procedure to account for variations in sample size was employed. Prior to the commencement of this study a difference was noted between groups based on students' scores on the first hour exam. The treatment group had a significantly higher mean exam score than the control group. Students' SAT scores and course grades were used as covariates in the statistical analysis to control for potential differences in academic ability that may have existed between students in each group prior to commencement of this study.

Analysis of covariance techniques permitted refined estimates of experimental error. In addition, the analysis of covariance techniques allowed adjustments of treatment effects to be made for any differences that may have existed between students in each group prior to commencement of this study.

Qualitative Analysis

Qualitative data were obtained from the written activities performed by the students. These data included responses to assigned folder activities, laboratory questionnaires, and post-lab activities.

One folder activity was designed to uncover students' perceptions of their learning styles prior to the administration of the Productivity Environmental Preference Survey. An additional folder activity was given after students had received their learning style profiles. An analysis of student responses to these activities is presented in Chapter 4. Responses to this activity yielded information regarding students' feelings about the accuracy of their learning style profiles. In addition, a comparison was made between students' perceptions of their learning styles and the results obtained from the learning style assessments.

One folder activity related to student ability to interpret motion graphs was given prior to commencement of the instructional treatments. Information obtained from this activity permitted a comparison of student ability to interpret motion graphs before they had received the treatments.

A laboratory questionnaire was administered after each instructional treatment. Analysis of student responses provided information regarding particular aspects and/or factors that influenced their attitude and motivation toward performing the laboratory activities. Furthermore, analysis of student responses involved uncovering common themes and factors that influenced student attitude and motivation. These responses also served to enforce the observations that were made as students performed each activity.

A post-lab activity was also administered after each instructional treatment. The post-lab activities focused on student ability to interpret motion graphs. Some questions posed pertained directly to the activities that had been performed during the laboratory, while other questions required students to extend their knowledge beyond that which was performed during the laboratory. Student responses were quantified to permit comparisons to be made between students in each group.

Summary

In this chapter, the research design, procedures for the study, and data analysis techniques were presented. A main focus of this study was the determination of the role(s) that individual learning style differences may have on students' ability to understand basic kinematics concepts following laboratory instruction using interactive digital video techniques. Particular attention was given to student ability to understand kinematics concepts via the construction and interpretation of motion graphs. Various assessment measures utilized have also been described within this chapter. Student learning styles were assessed using the Productivity Environmental Preference Survey and a brief discussion was included. Furthermore, the Test of Understanding Graphs in Kinematics administered to participating students was described within this chapter. The results from a preliminary study performed with students in the *Survey of Physics* classes at South Dakota State University were also presented. The qualitative and quantitative data collection measures used in this study were described. Finally, the statistical analysis techniques employed in this study were outlined.

CHAPTER 4

RESULTS OF THE STUDY

A summary of the results of students' learning style assessments is presented and described. In addition, results of students' performance on the Test of Understanding Graphs in Kinematics are presented and discussed. Research findings regarding student motivation and attitude and their relationship to enhanced student performance and understanding of kinematics concepts are described. Results and findings are presented in relation to each hypothesis and research question. Results from folder and post-lab activities are also presented.

About the Students Participating in this Study

During the course of this investigation, no attrition occurred among participating students. As indicated in Chapter 3 students who enroll in this course do so to satisfy American University's General Education requirement for graduation. Hence, the likelihood of a student dropping the course during the period of the study was minimal from the outset.

Some very minor fluctuations occurred between the total number of students enrolled in the laboratory and the number of students represented in the results that follow. For example, one student who was part of the control group was totally blind. Hence, he was not able to fully participate in the laboratory activities. This student did attend all labs and participated to the extent that he could. However, he was obviously not able to draw and interpret motion graphs. Furthermore, this student did not take the Test of Understanding Graphs-Kinematics. He did however, take the learning style assessment and all regular classroom examinations. In addition, there were two other male students in the control group who had originally indicated that they did not wish to participate in the study. However, one of these individuals later decided to take the learning style assessment and both students willingly took the Test of Understanding Graphs-Kinematics. For these reasons, some minor fluctuations occur in the number of participants represented in the statistical analysis.

Laboratory Observation

While these two laboratory experiments were being conducted, informal observations were made by this researcher, and each laboratory session was videotaped. Further, each of the teaching assistants, Nawal and Xing-Cheng, offered their observations regarding the laboratory activities at the conclusion of each session. During the first week that the laboratories were being conducted, Sarah, the individual responsible for the TOOLBOOK programming of the VIDSHELL interactive digital video activities, was present and offered her observations as well. Sarah was also present during the preliminary study conducted with students at South Dakota State University in the spring semester of 1995, so her comments were particularly noted. A discussion of these laboratory observations is presented later in this chapter as they relate to the research questions posed.

Results of the Productivity Environmental Preference Survey

Prior to taking the Productivity Environmental Preference Survey, students were asked to describe their learning style through the first folder activity. Students were not given any strict rules to follow with this writing assignment. Rather, they were encouraged to think about such factors as the learning environment, the time of day in which they learned best, and whether they preferred working in a group or alone. The intent in giving this assignment was to encourage students to think about their individual learning preferences before the Productivity Environmental Preference Survey was administered.

Students responded to this activity in a variety of ways. Many students expressed that they were delighted to have a college professor interested in how they learned. The students were very willing to discuss their learning preferences. Comments from several students suggested that they did not feel they really had a definite learning style. "My learning style is not one that is very unique" was articulated over and over again throughout the students' discussions of their styles. Furthermore, several students indicated that they had never even thought about their learning style until they were asked to write about it. In their discussions some students shared thoughts based on their experiences in elementary through high school. Other students noted their learning styles in terms of how they felt they could best learn physics or some other science-related subject. Students also commented on how they learned best both inside and outside of the classroom. Some students related their learning style to particular teaching styles that they felt best accommodated them. Comments from one international student stressed the pressure of going to school in another country and how the demands and expectations of teachers in their home country differed from those of teachers here in the United States.

Because this writing assignment was open-ended, the depth of student responses varied. Several students expressed great detail when describing their learning styles. Many brought up areas like structure and the need to work with or without sound while they were learning. Other students suggested that if they were interested in what they were learning they could learn better, regardless of their learning style. Still other students discussed distracters and how outside pressure affects their learning. Many students also related learning styles to their study habits. Overall, student comments about their learning styles were regarded as honest and sincere. Some students even expressed that learning just wasn't a priority for them!

After students had received their learning style profiles, they were asked to discuss the results through a second folder activity. The student who was blind was particularly enthusiastic about the results he received. In a one-on-one discussion with him, he shared that this was one of the first times in his life he had ever felt like he was not being stereotyped because of his vision impairment. One comment he made was, "Just because I can't see doesn't mean I learn the same way that every other person who can't see does!"

A comparison was also made between student comments regarding their learning styles and the results obtained from the learning style assessments. Students' comments regarding their learning styles did not address all of the elements assessed by the Productivity Environmental Survey. However, student perceptions of particular elements addressed by the learning style instrument were noted to be congruent with the results they received.

Overall, responses revealed that a majority of students felt the results they received closely paralleled their own learning styles. In addition, many students indicated that they had never considered some of the elements that can influence how they learn. For example, some students indicated that they had never thought elements such as time of day, and how the need for sound and structure influenced how they learn. Students' comments confirmed the analysis of their learning styles performed in the first folder activity. Many students indicated that the results obtained from the Productivity Environmental Preference Survey encouraged them to think more deeply about learning styles.

Learning Styles Assessment - Focus on Specific Items

Of particular interest in this study were students' scores on the Productivity Environmental Preference Survey learning style assessment on the auditory, visual, tactile, kinesthetic, motivation, and structure elements. Learning style data for 64 students were included in this analysis.

Results of the learning style assessment for the six elements of interest for all students participating in the study (n = 64) with scores ≥ 60 are shown in Figure 1. The results presented here indicate that 12.50% had scores in the high category for motivation and 60.94% had scores in the high category for structure. In regard to the modality elements, 39.06% had high scores on the auditory, 6.25% had high scores on the visual, 25.00% had high scores on the tactile, and 15.63% had high scores on the kinesthetic element.

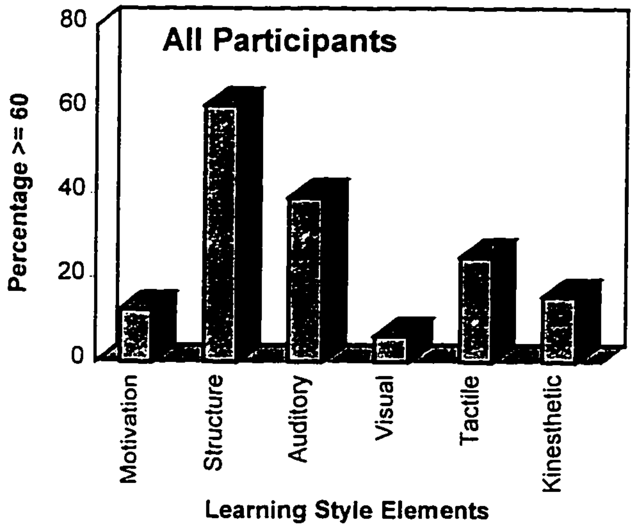


Figure 1. Learning Style Assessment Results for All Participants with Scores ≥ 60

Figure 2 shows results of the learning style assessment for all students with scores ≤ 40. These results indicate that 15.63% had scores in the low category for motivation and 1.56% had scores in the low category for structure. Results for the modality elements indicate that 7.81% had low scores on the auditory, 20.31% had low scores on the visual, 7.81% had low scores on the tactile, and 3.13% had low scores on the kinesthetic element. Figures 1 and 2 are also used to facilitate a comparison between the learning styles of all students participating in this study in relation to the students within each group.

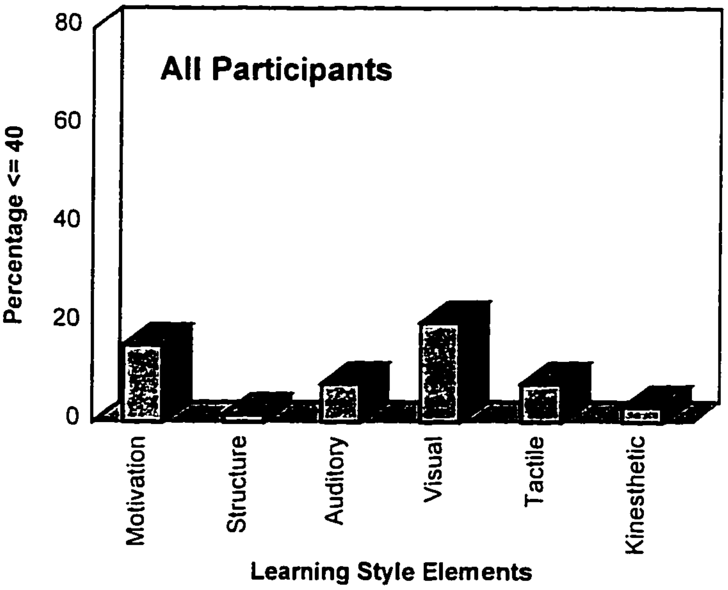


Figure 2. Learning Style Results for all Participants with Scores ≤ 40

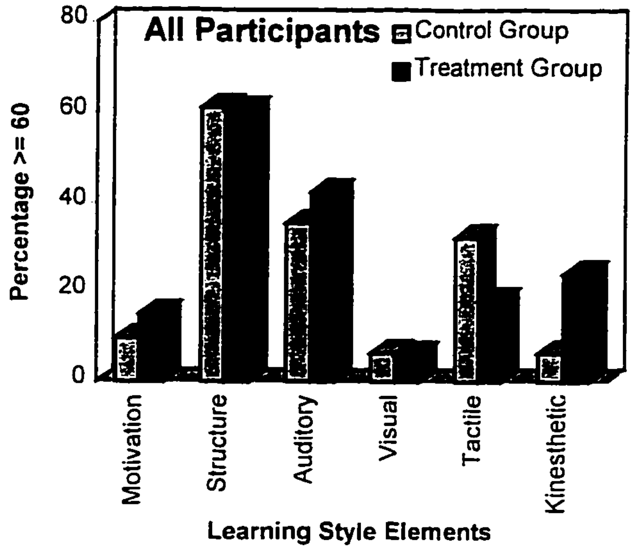


Figure 3. Learning Style Results by Instructional Group with Scores ≥ 60

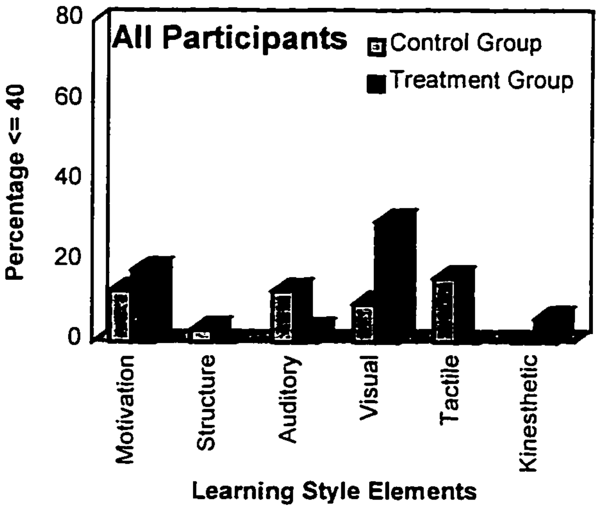


Figure 4. Learning Style Results by Instructional Group with Scores ≤ 40

The learning style assessment results can be further analyzed through a comparison of scores for students in the treatment and control groups (Figures 3 and 4). A comparison of these results to those for all participants indicates that the treatment and control groups consisted of students whose learning styles are similar. Some differences are noted. however.

The treatment group had a slightly higher percentage of students with kinesthetic preferences than did the control group (Figure 3). In addition. the control group had a higher percentage of students with tactile preferences than did the treatment group.

An individual scoring low on the visual element would not prefer to learn new and difficult information via a visual medium. The interactive digital video activities used by students in the treatment group were highly visual. The results presented here indicate that approximately one-third of students in the treatment group do not prefer to learn new information through visual means. Implications in terms of student performance on the Test of Understanding Graphs-Kinematics in relation to the visual modality are presented in Chapter 5.

Results presented in Figure 4 further indicate that over 16% of the students in the control group scored low on the tactile element as opposed to no students in the treatment group who scored low on this element. The laboratory activities performed by both groups had a strong tactile component. Again, implications regarding this difference in tactile preferences between groups as they relate to student performance on the Test of Understanding Graphs-Kinematics are discussed in Chapter 5.

Of additional interest in this study is the analysis of learning style assessment results by gender. Figure 5 shows composite results for all students who scored high on the six elements of interest analyzed by gender. These data analyzed by instructional group as well as by gender are displayed in Figures 6 and 7.

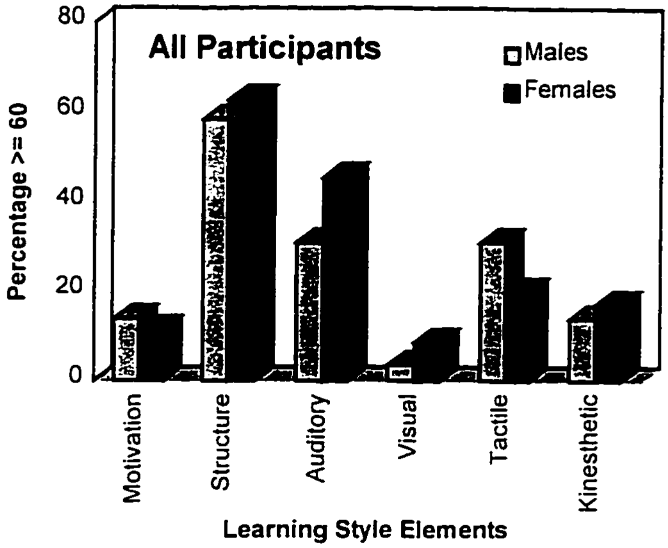


Figure 5. Learning Style Results by Gender for all Participants with Scores ≥ 60

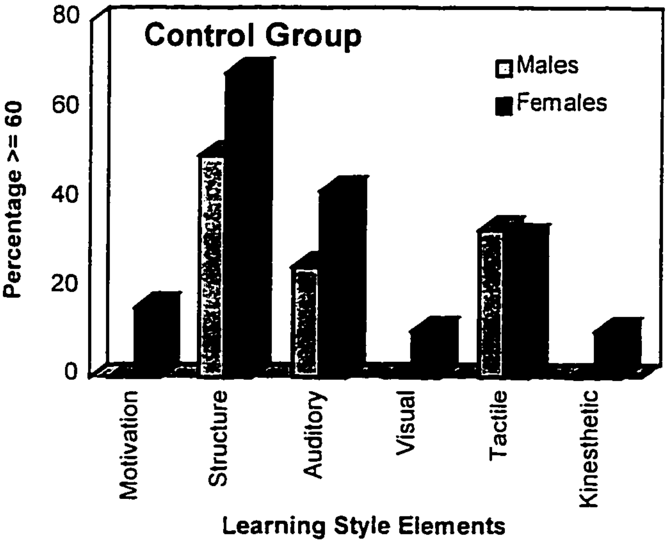


Figure 6. Learning Style Results by Gender for Control Group with Scores ≥ 60

Upon inspection of the graphs shown in Figures 5, 6 and 7 the kinesthetic element stands out. Figure 5 indicates that 13.79% of all males and 17.14% of all females participating in this study displayed strong preferences on the kinesthetic element. Figure 6 reveals that no males and just 10.53% of the females in the control group had strong preferences on the kinesthetic element. Figure 7 shows, however, that for students in the treatment group, 23.53% of the males and 25.00% of the females had strong preferences on this element.

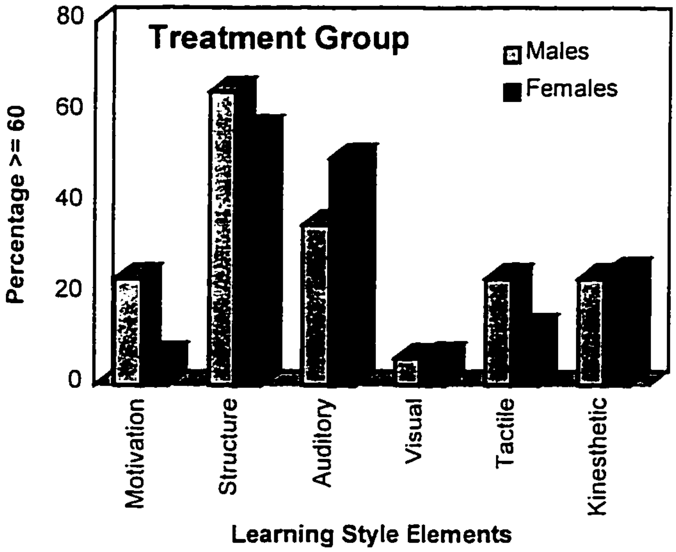


Figure 7. Learning Style Results by Gender for Treatment Group with Scores ≥ 60

Both treatment and control experiments had a similar kinesthetic component. However, the activities performed by the control group for the *Freefall* laboratory had a slightly stronger kinesthetic component than those performed by the treatment group. The kinesthetic component for the *Projectile Motion* laboratory was similar for each group; however students in the treatment group had to spend time sitting at the computer while performing their analyses.

Further inspection of Figure 6 reveals that a larger percentage of females in comparison to males in the control group scored high on the motivation element. More females in the control group displayed a strong preference for structure. The laboratory activities were not open-ended, and therefore provided much structure. In addition, students in both groups followed structured, written laboratory procedures.

Figure 7 shows that a larger percentage of males in the treatment group scored high on the motivation and tactile elements. A discussion in Chapter 5 addresses whether higher scores on the motivation and tactile elements can be related to increased performance on the Test of Understanding Graphs-Kinematics for the two instructional groups.

Figure 8 yields the composite results analyzed by gender for all students who scored low on the six elements of interest. Figures 9 and 10 show these results further divided by instructional group and by gender. Upon comparison of Figures 8, 9, and 10, two elements stand out. The first is the visual element. Figure 8 reveals that 20.69% of all males and 17.14% of all females participating in this study did not display a visual preference. Figure 9 indicates that within the control group 8.33% of the males and 10.53% of the females did not have a visual preference. However, 29.41% of the males and 31.25% of the females in the treatment group did not display a visual preference.

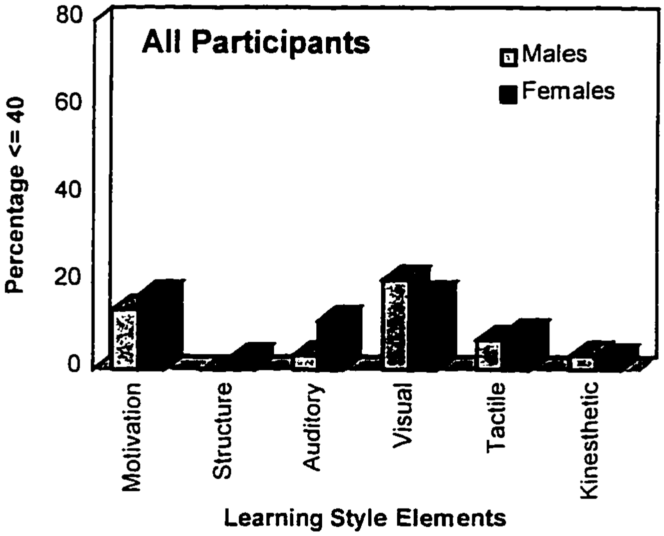


Figure 8. Learning Style Results by Gender for All Participants with Scores ≤ 40

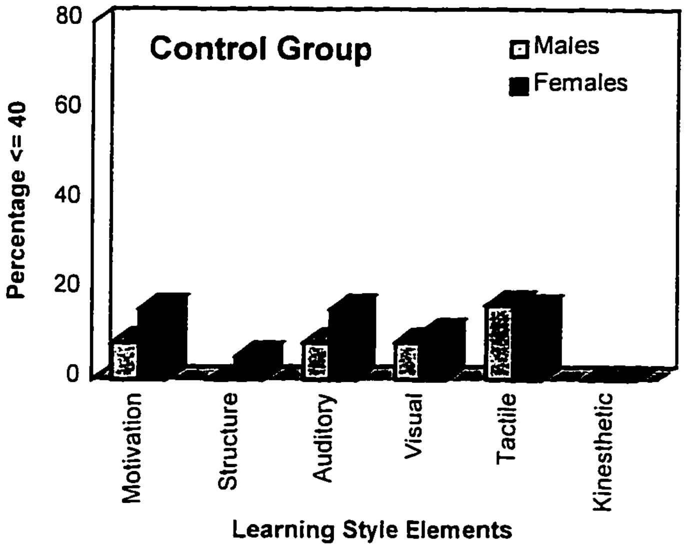


Figure 9. Learning Style Results by Gender for Control Group with Scores ≤ 40

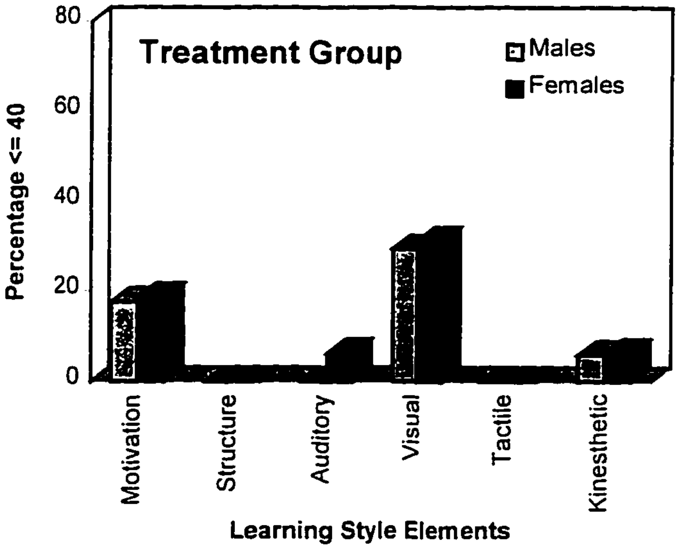


Figure 10. Learning Style Results by Gender for Treatment Group with Scores ≤ 40

Implications in terms of the relatively high percentage of students with low scores in the visual modality and performance on the Test of Understanding Graphs-Kinematics are discussed in Chapter 5. The percentages of males and females scoring low on this element were very similar within each instructional group. Furthermore, a larger percentage of students (males and females) in the treatment group did not display a visual preference. This result is particularly noted since the interactive digital video laboratory activities for the treatment group were highly visual in nature.

Results of the Statistical Analysis

Analysis of Variance on SAT Scores

In conducting this analysis, Scholastic Achievement Test (SAT) scores were obtained for forty-eight of the sixty-eight students who participated in this study. SAT scores were not available for any student in the course who transferred to American University with more than 22 credits or for the international students participating in this study. An analysis of variance for SAT scores is given in Table 1.

Results shown in Table 1 reveal a statistically significant difference in SAT scores between instructional groups [$F(3, 47) = 5.59, p \leq .05$]. Results indicate a mean SAT score of 1073 for the control group and 1206 for the treatment group. Because SAT scores are commonly treated as a predictor of students' academic ability, these results suggest that a difference in academic ability levels may have existed between students in each group prior to commencement of this study.

Table 1 also indicates that no significant difference exists between students' SAT scores based on gender. These results further indicate that no interaction effects exist between treatment and gender.

Table 1. Analysis of Variance on SAT Scores

Source	Sum of Squares	df	Mean Square	F	p
Treatment	47810.742	1	47810.742	5.59	.022
Gender	214874.134	1	214874.134	1.24	.270
Treat × Gender	41907.349	1	41907.349	1.09	.302
Error	1806591.100	47	38438.109		

Results of Analysis of Variance on Course Grades

The significant difference in SAT scores between instructional groups suggests a potential difference in academic ability levels existed between students in each instructional group at the beginning of this study. Students' course grades, which are assumed to be a measure of student ability to learn a topic, were analyzed to further explore this difference. Course grade was measured by total points (maximum = 900 points) in the class. Analysis of variance techniques were employed for course grades and the results are given in Table 2. These results show that no significant difference exists in course grades based on treatment, gender or their interactions. Although differences were noted between groups based on SAT scores, these differences were not observed based on course grade.

Table 2. Analysis of Variance on Course Grade

Source	Sum of Squares	df	Mean Square	F	p
Treatment	5336.00	1	5336.00	0.75	0.391
Gender	482.89	1	482.89	0.07	0.796
Treat × Gender	20661.05	1	20661.05	2.89	0.094
Error	428613.94	60	7143.57		

ANCOVA Results for the Test of Understanding Graphs-Kinematics

The results of the ANCOVA for the Test of Understanding Graphs-Kinematics are given in Table 3. This analysis included seven covariates, SAT scores and scores on auditory, visual, tactile, kinesthetic, motivation and structure elements of the Productivity Environmental Preference Survey.

The results presented in Table 3 indicate that none of the learning style covariates are significant, hence, they were dropped from the statistical model. These results further indicate that treatment effects are not significant.

An analysis of covariance was conducted on the Test of Understanding Graphs-Kinematics using SAT score and course grade as covariates. The results of this ANCOVA are presented in Table 4.

Results shown in Table 4 indicate a significant difference [$\underline{F}(1, 42) = 4.15$, $\underline{p} = 0.048$] exists on mean scores of the Test of Understanding Graphs-Kinematics between males and females. After adjusting for SAT and course grade, the mean score on the test of Understanding Graphs-Kinematics is 10.19 for females and 12.77 for males.

Table 3. Analysis of Covariance on the TUG-K (supporting Purpose 1)

Source	Sum of Squares	df	Mean Square	F	p
Treatment	2.803	1	2.803	0.16	0.699
Gender	37.734	1	37.734	2.18	0.148
Treat × Gender	5.216	1	5.216	0.30	0.586
SAT	401.569	1	401.569	23.19	0.000
Auditory	8.702	1	8.702	0.50	0.483
Visual	1.428	1	1.428	0.08	0.776
Tactile	0.002	1	0.002	0.00	0.992
Kinesthetic	2.312	1	2.312	0.13	0.717
Motivation	1.315	1	1.315	0.08	0.784
Structure	6.186	1	6.186	0.36	0.554
Error	640.722	37	17.317		

Based on the results presented in Table 4 no significant difference in mean scores on the Test of Understanding Graphs-Kinematics exists between instructional groups when SAT score and course grade are treated as covariates. These results also show that no significant treatment by gender interaction effect exists.

Interaction effects were tested on mean scores on the Test of Understanding Graphs-Kinematics based on course grade and gender and the results are presented in Table 5. These results show that a course grade by gender interaction effect is not present.

Table 4. Analysis of Covariance on TUG-K (supporting Purpose 2)

Source	Sum of Squares	df	Mean Square	F	p
Treatment	0.037	1	0.037	0.00	0.964
Gender	73.077	1	73.077	4.15	0.048
Treat × Gender	21.403	1	21.403	1.22	0.277
SAT	35.234	1	35.234	2.00	0.165
Grade	225.723	1	225.723	12.82	0.001
Error	739.379	42	17.604		

Table 5. Results of the Analysis of Covariance on TUG-K (Interaction Effects)

Source	Sum of Squares	df	Mean Square	F	p
Treatment	22.527	1	22.527	1.22	0.274
Gender	4.318	1	4.318	0.23	0.631
Treat × Gender	1.806	1	1.806	0.10	0.756
Grade	367.957	1	367.957	19.92	0.000
Grade × Treat	22.111	1	22.111	1.20	0.279
Grade × Gender	0.842	1	0.842	0.05	0.832
Grade × Treat × Gender	0.625	1	0.625	0.03	0.855
Error	1015.954	55	18.472		

Relationship Between TUG-K Scores, SAT Scores, Course Grades, and Gender

Results of the analysis of variance (ANOVA) performed on both SAT scores and on course grades testing treatment, gender and their interactions, reveal a mean course grade of 693.71 for females and 688.14 for males, a difference which is not statistically significant. The mean SAT score was 1171 for females and 1108 for males, again a difference which is not statistically significant. Females in this study had slightly higher mean SAT scores and mean grades than males, yet significantly lower mean scores on the Test of Understanding Graphs-Kinematics.

A correlation analysis was performed for males and females comparing mean scores on the Test of Understanding Graphs-Kinematics, SAT scores and course grades. Results of the correlation analysis for males and females are shown in Tables 6 and 7, respectively.

Table 6. Correlations Between TUG-K, SAT, and Grades for Males

	TUG-K	SAT	GRADES
TUG-K	1		
SAT	.387	1	
GRADES	.397	.153	1

Table 7. Correlations Between TUG-K, SAT, and Grades for Females

	TUG-K	SAT	GRADES
TUG-K	1		
SAT	.823	1	
GRADES	.586	.573	1

Correlations between mean scores on the Test of Understanding Graphs-Kinematics, SAT scores and course grades are quite strong for females. A strong correlation exists between SAT scores and mean scores on the Test of Understanding Graphs-Kinematics for females (r = .823). This result suggests that a female with a high score on the SAT would have a correspondingly high score on the Test of Understanding Graphs-Kinematics, and vice versa. A reasonably strong correlation exists between course grade and mean scores on the Test of Understanding Graphs-Kinematics for females (r = .586).

Correlations between mean scores on the Test of Understanding Graphs-Kinematics and SAT scores (r = .387) and between mean scores on the Test of Understanding Graphs-Kinematics (r = .397) and course grades are not as strong for males. Given that males have a significantly higher overall mean score on the Test of Understanding Graphs-Kinematics than do females, these results are somewhat surprising. These results indicate that SAT scores and course grades are better predictors of performance on the Test of Understanding Graphs-Kinematics for females than for males.

A comparison of SAT scores and course grades shows that a weak correlation exists for males (r = .153) suggesting that the SAT is not a strong predictor of class performance. In addition, this low correlation coefficient might be an indicator that the males in this study were not working to their potential in the class as predicted by their SAT scores.

The correlation between SAT and grades is stronger for females with r = .573. The correlations between SAT and course grades suggests that the SAT is a better predictor of class performance for females than for males. This analysis suggests that more variance in mean scores on the Test of Understanding Graphs-Kinematics can be explained with SAT scores for females than for males. In addition, more variance in mean scores on the Test of Understanding Graphs-Kinematics can be explained with course grades for females than for males.

In addition, these results tend to suggest that if SAT course and course grade are predictors of academic success, as is their common interpretation, then one would expect females to have mean scores on the Test of Understanding Graphs-Kinematics that are comparable to males (as suggested by SAT scores and course grades). Based on the similarities between SAT scores and course grades between males and females, the expectation might be that males and females would also have congruent scores on the Test of Understanding Graphs-Kinematics. However, females scored significantly lower on the Test for Understanding Graphs-Kinematics than males. One explanation for these differences in mean scores may be that a gender bias is inherent in the Test of Understanding Graphs-Kinematics.

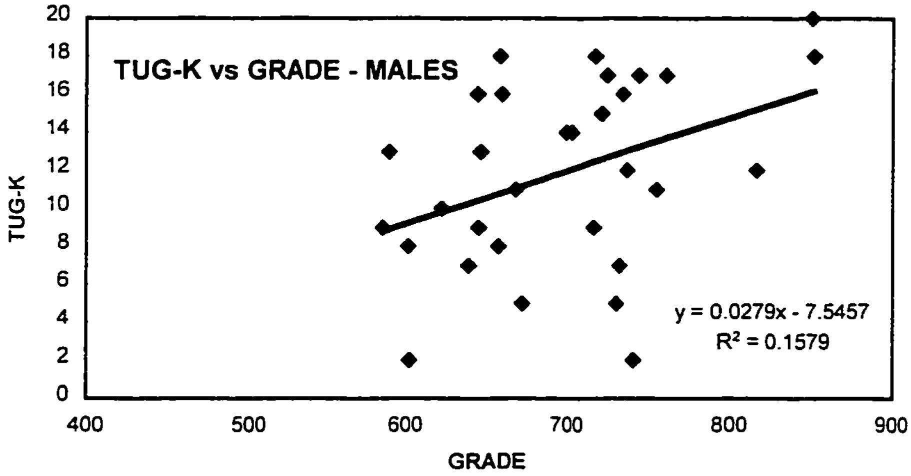


Figure 11. TUG-K Score vs Grade for Males

Graphical representations of the regression lines for mean scores on the Test of Understanding Graphs-Kinematics versus course grades for males and females are given in Figures 11 and 12, respectively. Figure 11 shows a weak correlation between mean scores on the Test of Understanding Graphs-Kinematics and course grades for males. Scores for the males tend to cluster toward higher scores on both measures. Figure 12 shows a stronger correlation exists between mean scores on the Test for Understanding

Graphs-Kinematics and course grades for females. These results suggest that course grade is a better predictor of performance on the Test of Understanding Graphs-Kinematics for females than for males.

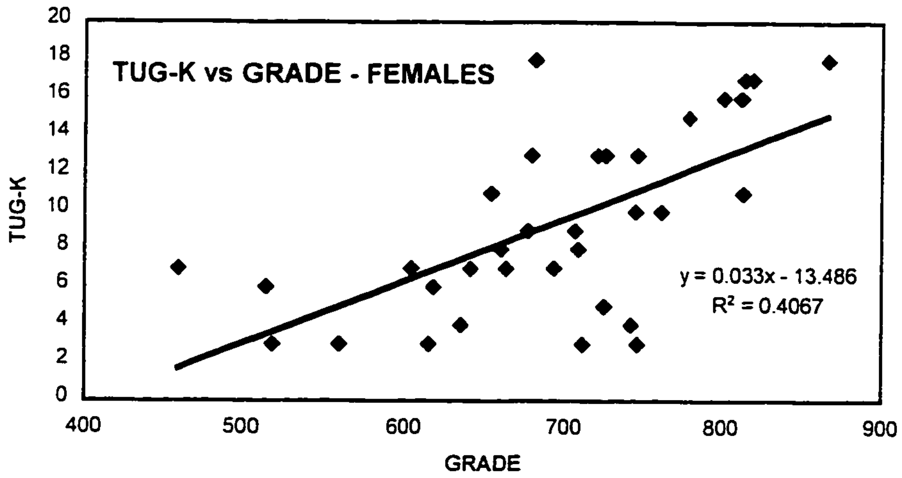


Figure 12. TUG-K Score vs Grade for Females

Overall, the statistical analyses performed indicate that neither treatment nor learning style is a significant factor in relationship to student performance on the Test of Understanding Graphs-Kinematics. When differences in student ability levels are accounted for using SAT scores and course grades, a significant difference remains between mean scores on the Test of Understanding Graphs-Kinematics when testing gender. These results suggest a possible gender bias exists in the Test of Understanding Graphs-Kinematics. The implications of these results will be further discussed in Chapter 5.

This ends the formal quantitative analysis conducted in this study. However, results from other observations are presented to help support and make clear this analysis. In addition, results from student writing activities are also presented to enhance and support results presented in the quantitative analysis.

Effects of Instructional Treatments on Student Attitude and Motivation

Several measures were used to examine students' attitudes and motivational levels as they performed the laboratory activities. Informal observations were made by this researcher and the teaching assistants, Nawal and Xing-Cheng, as the students performed the laboratory activities. Sarah, the individual responsible for programming the modifications to VIDSHELL, was present during the first laboratory activity at American University as well as during the preliminary study at South Dakota State University. For this reason her observations were noted.

During his observations Xing-Cheng noted that students in the control group seemed to come with calculator in hand and then just perform the tasks as outlined in the laboratory manual. He noted, however, that students in the treatment group seemed to focus more on the video. Xing-Cheng observed that these students appeared to be very interested in the analysis of the video. As a result of the observations, he suggested that students in the treatment group were spending more time with their data and their graphs.

Nawal observed that students in the treatment group seemed to focus less on the required calculations and more on the technical aspects of the computer activity, especially during the first laboratory activity. She also noted that the students seemed to focus less on the technical aspects of the activity and more on the physics concepts after having worked with the computers during the first laboratory. Upon grading the laboratory reports Nawal further indicated that she did not notice any large differences between students in the control and treatment groups in terms of their understanding of the kinematics concepts. Further, students in both groups seemed to have a positive attitude toward the activities they performed, and overall were highly motivated.

Sarah noted that students appeared to be very conscientious and worked hard to make the activities "work out." She also noted that students were very excited about having the opportunity to work with the technology. Sarah observed that students really enjoyed using the video camera and capturing their own data.

My observations during the laboratory sessions paralleled those of Nawal, Xing-Cheng and Sarah. I noted that students using the interactive digital video tools expressed a feeling of self-satisfaction in that they were able to work successfully with and use the technology. Some students commented that they felt more "sophisticated" when they were using the computers.

Videotapes were made during each laboratory session and analyzed to support the informal observations made. From the video tapes, I noted that most students were motivated and maintained a positive attitude toward learning. This observation was made by listening to the dialogue between students as they worked with their partners to complete the activities. Students in both instructional groups expressed that they really liked the activities and felt they were able to make deeper connections with the material that was presented in lecture.

Students in both the control and the treatment groups were quite enthusiastic about the experiments. Because these groups performed different activities, the reasons for their enthusiasm were examined through a questionnaire administered immediately after they had completed each activity and before they left the laboratory.

When asked about what aspects of the freefall laboratory were most helpful, students in the control group said they liked being able to work in groups and exchange ideas with others. A common response expressed by several students was the satisfaction they experienced from having the opportunity to perform hands-on activities.

These students felt that the hands-on experience helped them to make better connections with the material being presented in class. Other students found drawing the graphs helpful. One student indicated that "Actually calculating and plotting [the graphs] makes it more real." Another student commented that the laboratory activity helped to make the concept of freely falling objects understandable. The visual aspect of the lab was also noted by several students. Two students articulated that their data (i.e. data tape showing the distance the object fell through as a function of time) helped solidify the concept that a falling object moves through greater distances in each interval of time because it was constantly accelerating. Other students indicated that having to do some calculations was useful in terms of helping to make the necessary connections between distance and time for a falling object. Not all students found the laboratory exercise helpful, however. Comments from a small number of students suggested that they disliked having to draw the graphs by hand because they felt it was busywork.

Students in the treatment group also responded to the same questionnaire. In regard to what was most helpful about the laboratory exercises, a common them emerged among students in the treatment group. Approximately half of the students responding indicated that seeing their captured video displayed on the computer monitor was useful. After completing the first laboratory activity on freefall many students in this group noted that seeing the graphs of position-, velocity-, and acceleration-versus-time generated on the screen simultaneously with the motion of the ball was very informative. Several students expressed that the computer was a good tool in terms of helping them understand the objectives of the activity. Others noted that using the computer helped make the activity more interesting for them. One student noted "I liked putting all the things I've learned together and figuring problems out."

Upon completion of the second laboratory activity on projectile motion, students in the control group expressed their overall satisfaction. These students were able to use computers as a mechanism for measuring the time it took their projectile to move between two photocells in order to determine its initial horizontal velocity. Several students commented that they really thought that using the computers was helpful.

A comparison of responses from students in each group revealed one common difference. Students in the control group articulated confusion with the graphs they were asked to draw. No students in the treatment group commented on confusion in drawing the graphs. Although the data collection methods varied for the two groups, all students were required to do the same graphical analysis by hand as part of their formal laboratory reports.

Upon grading the written laboratory reports, Nawal noted that students in both groups performed similarly. My observation of the written laboratory reports paralleled that of Nawal. Written reports submitted by all students were quite good, including the sections where graphs were drawn and interpreted. Criteria used to assess students' reports included timeliness, completeness, and accuracy of conclusions made. Students were given one week to complete the written laboratory report, and hence had considerable time to get their questions answered before submitting a final report. Thus, most students should be able to turn in good quality written reports.

Upon comparison, students in both groups were enthusiastic about the activities performed. Students in the control group expressed that drawing the graphs helped them to understand the physics concepts better. Other students in the control group found drawing the graphs very confusing. Overall, students in the control group made numerous comments in regard to drawing the graphs. However, students in the treatment group indicated that the use of the computer to view the motion of the object and the associated graphs was most helpful in terms of understanding concepts. In addition, comments from students in the treatment group placed little emphasis on the graphing aspect of the exercises. No students in the treatment group expressed frustration or confusion in drawing the graphs.

No differences in attitude or motivation were observed between students in either treatment group. However, the factors which contributed to their motivation and positive attitudes differed. Students in the control group liked the hands-on aspect of the exercises, while students in the treatment group liked working with the videos. Students in the treatment group were more motivated to conduct repeated analyses of their results than were students in the control group. Students in the treatment group found it easier to repeat the analyses of their data since they could simply reload the video they had captured and begin again. These students were also more motivated to analyze and discuss amongst themselves the graphs that were produced as they worked with the computers. Much group discussion was observed between students in the treatment group. Many students would focus on comparing their expected results to their actual results and hence, spent more time discussing them.

Results of Post-lab Activities

The first post-lab activity was administered following the *Freefall* laboratory and consisted of three questions. Because this motion was analyzed by both instructional groups during the laboratory session these questions revealed students' ability to display, immediately after performing the activity, their understanding of the motion they had observed. The post-lab questions for the *Freefall* laboratory are shown below. Results of student responses are given in Tables 8 and 9.

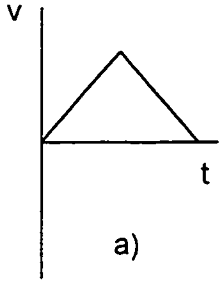
Analysis of student responses to Question 1 show a larger number of students in the treatment group who were able to produce correctly and explain both graphs. In addition, several others were able to draw correctly one of the two graphs. Students had the most trouble drawing the position-vs-time graph. Many students were able to draw correctly the acceleration-vs-time graph. None of the students in the treatment group drew both graphs incorrectly. These results suggested that students in the treatment group who viewed these same graphs on the computer monitor as they worked with their captured video were more successful in reproducing graphs that paralleled what they had just observed during the laboratory.

Question 1

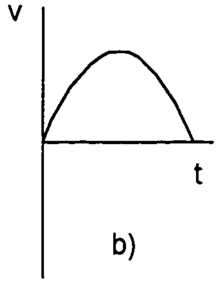
Today you looked at the motion of an object that was dropped and allowed to fall freely to the ground. In order to determine the acceleration of the object, you made a plot of the average velocity of the object versus time and determined the slope of the straight line. On the graphs below, sketch what you think the position-versus-time and acceleration-versus-time graphs should look like for this motion. Explain your reasoning.

Question 2 A

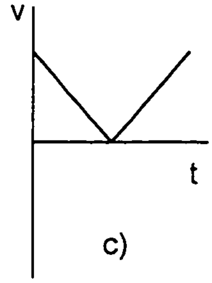
Now assume that you throw a ball into the air and then it falls back to the ground. Neglecting air resistance, which of the graphs shown below best illustrates the variation in the ball's velocity with respect to time? Explain your reasoning.



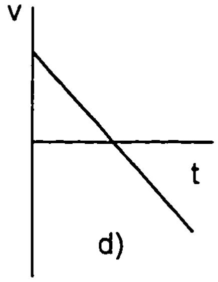
a)



b)



c)



d)

Question 2 B

Sketch what you think the position-versus-time and acceleration-versus-time graphs would look like for the motion as described in part A. Again, explain your reasoning.

Table 8. Results of Post-lab Activity #1 (Questions 1 & 2B)

Question	Treatment Group Responses			Control Group Responses		
	Both graphs correct	One graph correct	No graphs correct	Both graphs correct	One graph correct	No graphs correct
1	23	10	0	12	12	6
2 B	3	19	9	1	20	9

Further analysis of student responses to Question 1 reveals that fewer than half the students in the control group could correctly draw both graphs. Of the students able to produce one of the two graphs, most were able to correctly produce the acceleration-versus-time graph. These students appeared to recognize that the acceleration of the falling object was constant. However, they had great difficulty producing the position-vs-time graph. Many could correctly explain that the object was covering greater distances as it fell, but could not translate this into a graphical representation. Of the 6 students who drew both graphs incorrectly, several drew a straight line with a positive slope for each of the two graphs, arguing that the object kept accelerating as it fell. Others drew and correctly explained the graph for the velocity of the falling object, instead of producing a position-vs-time graph as requested.

Table 9. Results of Post-lab Activity #1 (Question 2A)

Treatment Group Responses				Control Group Responses			
a	b	c	d*	a	b	c	d*
0	2	26	5	1	7	14	8

* denotes correct response

Student responses to Question 2A are given in Table 9. Analysis of student responses to this question show a similar proportion of students in each group selecting the correct option. The most popular incorrect choice for both groups was (c). Students appeared to understand the fact that the speed of the ball decreased as it moved upward. Students also seemed to understand that the speed of the ball was zero at the highest point in its path. However, students appeared to have difficulty understanding what happened after the ball reached the highest point in its path. They could not translate the fact that the ball was speeding up while moving downward into the correct graphical representation.

Students in both groups had difficulty drawing the graphs required in Question 2B. These results are shown in Table 8. Several students in each group were able to correctly draw one of the two graphs. Many students were able to correctly draw the position-vs-time graph, but they could not produce the acceleration-vs-time graph. Most students realized that the acceleration of the object was constant, but could not translate that into the correct graphical representation. Several students in each group were unable to draw either graph correctly. Many of these students displayed similar difficulties when attempting to draw the acceleration-vs-time graph.

The post-lab activity for the *Projectile Motion* laboratory consisted of five questions which are given below. Student responses to Question 1 are summarized in Table 10.

Question 1

> Today you looked at the motion of an object that was projected horizontally. You theoretically as well as experimentally determined the horizontal range for your projectile. On the graphs below, sketch what you thin the position-, velocity-, and acceleration-versus-time graphs should look like for this motion. Do this for both the horizontal as well as vertical components of the ball's motion. Explain your reasoning for each graph.

Analysis of responses to Question 1 shows a large proportion of students in the treatment group who could correctly draw the position-, velocity-, and acceleration-versus-time graphs for the horizontal and vertical components of the projectile's motion. This result suggests that viewing the graphs plotted on the computer screen was a contributing factor to student success with this question. In addition, students in both groups who displayed difficulty drawing the position- and velocity-versus-time graphs were often able to correctly draw the graph representing acceleration-versus-time. Explanations given indicated that many students realized that the horizontal acceleration of the projectile was zero and that the vertical acceleration was constant. Incorrect responses given by students in both groups often displayed the "graph as a picture" confusion.

Table 10. Student Responses to Post-lab Activity #2 (Question 1)

Graph	Treatment Group		Control Group	
	Correct	Incorrect	Correct	Incorrect
Horizontal Position-vs-Time	20	13	8	16
Horizontal Velocity-vs-Time	27	6	20	4
Horizontal Acceleration-vs-Time	24	9	16	8
Vertical Position-vs-Time	18	15	3	21
Vertical Velocity-vs-Time	21	12	13	11
Vertical Acceleration-vs-Time	31	2	18	6

Questions 2, 3 and 4 did not involve graphical construction. Instead they were designed to uncover students' understanding about the meaning of the area under each of the curves. These questions are presented below. Table 11 yields a summary of student responses to these questions.

Analysis of Questions 2, 3, and 4 reveal similarities in the proportion of correct and incorrect student responses within each instructional group. Students in both groups had the most difficulty interpreting the area under the position-versus-time curve. Most students could not articulate that no physical significance is associated with the area under the position-versus-time graph. Many students tried to look at the units obtained from the area for each of the curves. Analysis of units allowed some students to obtain correct responses to the meaning of the area under the velocity- and acceleration-versus-time graphs.

Question 2

In your own words, describe what (if anything) the area under a position-versus-time curve represents.

Question 3

Describe what (if anything) the area under the velocity-versus-time curve represents.

Question 4

Describe what (if anything) the area under an acceleration-versus-time curve represents.

Table 11. Student Responses to Post-lab Activity #2 (Questions 2, 3, and 4)

	Treatment Group		Control Group	
Question	Correct	Incorrect	Correct	Incorrect
2	5	28	4	21
3	12	21	12	13
4	11	22	11	14

Question 5

How do you think your sketches would change if you instead launched the projectile upward at some angle instead of horizontally? Show your sketches below. Thoroughly explain your reasoning.

Table 12. Student Responses to Post-lab Activity #2 (Question 5)

Graph	Treatment Group		Control Group	
	Correct	Incorrect	Correct	Incorrect
Horizontal Position-vs-Time	21	13	6	18
Horizontal Velocity-vs-Time	26	8	15	9
Horizontal Acceleration-vs-Time	27	7	17	7
Vertical Position-vs-Time	7	27	13	11
Vertical Velocity-vs-Time	4	30	0	24
Vertical Acceleration-vs-Time	18	16	15	9

Summary

In this chapter the results of this study were presented. Results from the Productivity Environmental Preference Survey were shown. Students indicated that these learning style assessment results were very accurate indicators of their learning styles. Analysis of specific learning style elements revealed more students in the treatment group had kinesthetic preferences while more students in the control group had tactile preferences. The activities performed by group contained tactile as well as kinesthetic elements. The learning style results also show a higher number of students in the treatment group who did not display a visual preference for learning. Given the highly visual nature of the lab activities performed by these students. this result is particularly noted. Implications are presented in the next chapter.

Results from the data analysis performed revealed no significant relationship between the learning style covariates and mean scores on the Test of Understanding Graphs-Kinematics. These results suggest that the learning style elements of interest in this model did not have significant bearing on student performance on the Test of Understanding Graphs-Kinematics.

No statistical significance was found between instructional treatment and mean scores on the Test of Understanding Graphs-Kinematics after adjusting for SAT scores and course grades. The instructional treatments did not significantly enhance (or reduce) students' performance on the Test of Understanding Graphs-Kinematics.

Results from the data analysis revealed a significant difference was evident on mean scores of the Test of Understanding Graphs-Kinematics based on gender after adjusting for SAT scores and course grades. The results of the statistical analysis presented indicate that a possible gender bias exists on the Test of Understanding Graphs-Kinematics. A need remains to further investigate this assertion.

Results from observations and questionnaires were also presented regarding student attitudes and motivation as they performed the laboratory activities. These results suggested that overall, students in both groups had a good attitude and were highly motivated to perform the activities. The reasons for their positive attitudes and high levels of motivation were linked to the specific activities they had performed. Students working with the interactive digital video indicated that they liked to work with the computer to perform the required analyses. Students performing the traditional activities said they enjoyed the hands-on aspects to the labs.

Finally. an analysis was presented regarding student learning of kinematics concepts as evidenced by their ability to interpret motion graphs. Results of the post-lab activities were presented. These results showed that students performing the interactive digital video activities were more successful in responding to questions that closely paralleled the motion they had observed during the laboratory. However, students in both groups displayed similar difficulties when asked to extend their knowledge to a new situation involving graphical interpretation. Thus, the visual nature of the interactive digital video laboratories may contribute to students' successful reproduction of graphs that closely parallel what they had viewed during the laboratory.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

This chapter contains a summary, a discussion on learning styles and student learning in kinematics, conclusions, and the implications of this study to the field of physics education research. Significant results of this study are discussed and compared to results reported in the literature with emphasis on student ability to analyze and interpret kinematics graphs following instruction that utilized interactive digital video techniques. Results and findings reported in Chapter 4 are discussed as they relate to student understanding in kinematics. Gender issues raised regarding student performance on the Test of Understanding Graphs in Kinematics are discussed. Finally, implications and recommendations for future research are presented along with applications for teaching using interactive digital video techniques.

Summary of this Study

Much research has been conducted on student learning of kinematics concepts in introductory physics classes and laboratories (Halloun & Hestenes, 1985; McDermott, 1991; McDermott, Rosenquist & van Zee, 1987; Rosenquist & McDermott, 1987; Thornton & Sokoloff, 1990; Trowbridge & McDermott, 1980; van Heuvelen, 1991a). This research outlines many difficulties that students often have in understanding kinematics concepts. Other research has been reported that made use of interactive digital video techniques as well as computer-based laboratory techniques (Chaudhury & Zollman, 1994; Escalada & Zollman, in press; Escalada, Grabhorn & Zollman, 1996; Laws, 1991b; Thornton & Sokoloff, 1990; Zollman, 1994). Still other research has focused specifically on student ability to draw and interpret graphs of motion following instruction utilizing various types of video analysis software (Beichner, 1996; Brasell. & Rowe, 1993; Brungardt & Zollman, 1995).

Although results of research based on student learning in kinematics have been reported by these researchers, a theoretical framework specific to interactive digital video instruction has not, as yet, been developed. Therefore, unique pedagogical attributes of this type of instruction remain to be determined. This study aimed to contribute to the formation of a framework by which student learning gains could be assessed following instruction that made use of interactive digital video techniques.

Beichner (1994) reported that a single exposure to a motion event when working with a computer simulation is no better than traditional laboratory instruction. For this reason, two laboratory activities (*Freefall* and *Projectile Motion*) were developed for use in this study. Students in the treatment group performed these activities using an interactive digital video tool called VIDSHELL, while students in the control group performed these activities using traditional techniques.

Student learning of kinematics concepts was assessed, in part, using the Test of Understanding Graphs in Kinematics. Results of this study showed that students in the treatment group did not perform significantly better on the Test of Understanding Graphs-Kinematics than did students in the control group after adjusting for differences in SAT scores and course grades.

After controlling for SAT scores and course grades, a significant difference remains on mean scores of the Test of Understanding Graphs-Kinematics between students based on gender. A gender bias within the Test of Understanding Graphs-Kinematics may explain these results. Additional studies to investigated this noted gender difference are warranted.

Other measures of student learning of kinematics concepts involved analysis of student writing activities and analysis of graphical interpretation questions posed to them on two post-lab activities. Results of these analyses showed that students in the treatment group displayed less confusion when they responded to questions directly related to the laboratory activity they had performed. However, both instructional groups displayed similar levels of confusion when asked to extend their knowledge to questions that differed slightly from the particular activity they had performed in the laboratory. Students in the treatment and control groups displayed similar levels of confusion when they responded to somewhat unfamiliar questions. Although students in the treatment group were able to more effectively respond to questions that mirrored what they had done in the laboratory, they still held on to many misconceptions regarding motion concepts in general. Overall, student misconceptions regarding graphical construction and interpretation closely paralleled those reported in the literature.

The analysis of student learning styles using the Productivity Environmental Preference Survey was a component of this study. The relationship between learning styles and student ability to understand kinematics graphs following instruction that utilized both traditional as well as interactive digital video techniques was investigated.

Many physics education researchers have reported that learning styles were probably a factor in their results (Beichner, 1990; Pfister and Laws, 1995; Redish, 1994; Zollman, 1996; Zollman, 1997; Zollman and Fuller, 1994). However, no formal strategy has been employed by any researcher, to date, which would include as a component the assessment of student learning styles. Physics educators would like to believe that using various multimedia tools such as interactive digital video techniques will lead to improved attitudes, increased motivation, and enhanced learning of physics concepts. However, one overriding question must be addressed. Do these instructional tools work well for all students, regardless of their learning styles, or are students with some learning styles more responsive to these instructional strategies than students with other styles? In this study no statistically significant differences exist between learning style elements assessed and instructional techniques.

Discussion

Effects of Instructional Techniques

All students participating in this study were asked about their prior experience with graphing through a questionnaire on the first day of class. This question was asked in an attempt to compare their background experiences with graphing. Nearly every student in the class responded that they had some experience drawing and interpreting graphs within some context. Many students indicated that they had had extensive experience drawing and interpreting various types of graphs in the past. However. when confronted with kinematics graphs, many students displayed difficulty when asked to draw or interpret a graph. Thus, students entered the course with some knowledge of graphing. However students' experience working with kinematics graphs was very limited.

To assess further students' ability to understand kinematics graphs, one ten-point graphical interpretation question was given on the first classroom hour exam. The hour exam was given after formal lecture instruction on kinematics and before any laboratory treatments had been given. The mean score on this question for students in the control group was 7.06 ± 2.18 (n = 33), while the mean score for students in the treatment group was 7.15 ± 1.99 (n = 33). These results indicated that students in both groups were of similar ability in terms of interpreting kinematics graphs prior to commencement of the treatments.

Prior to performing the two laboratory exercises, students were given a folder activity in which they were asked to draw and interpret some basic motion graphs.

Given a position-vs-time graph, students were asked to draw the corresponding velocity- and acceleration-vs-time graphs. In addition, students were asked to compute the average velocity for particular time intervals as well as the instantaneous velocity at particular times from the position-vs-time graph. A similar number of students in both groups were able to accurately draw the corresponding velocity- and acceleration-vs-time graphs and calculate the average and instantaneous velocities. All students who were not able to draw the graphs displayed similar difficulties. Some students reproduced the position-vs-time graph for both the velocity- and acceleration-time graphs. This action was evidence of the "graph as a picture" difficulty described by other researchers (Brassell, 1987; McDermott, Rosenquist, & van Zee, 1986). Other students were able to accurately draw portions of the velocity- and acceleration-vs-time graphs.

One apparent difficulty was interpreting a curved portion on a position-vs-time graph. Most students recognized that they needed to determine a slope to find the average and instantaneous velocities. Students displayed less difficulty when determining the average velocity from the position-vs-time graph than when determining the instantaneous velocity from the same graph. The idea of constructing a line tangent to the curve at a particular time to determine an instantaneous velocity was troublesome for students in both groups. Students in both instructional groups displayed similar graphing abilities and experienced similar difficulties. These similarities were taken as further evidence that student graphical interpretation ability levels were similar prior to the commencement of the instructional treatments.

The Test of Understanding Graphs-Kinematics was used as one measure of student learning of kinematics concepts following the instructional treatments. A particular emphasis was on student ability to interpret motion graphs. Results of the statistical analyses performed reveal no significant difference on mean scores on the Test of Understanding Graphs-Kinematics between instructional groups [F (1, 47) = 0.00, p = .96] after adjusting for SAT scores and course grades. This result suggests that instructional treatments were not a significant factor in student performance on the Test of Understanding Graphs-Kinematics.

Relationship to Learning Styles

Learning style elements were assessed to explore relationships between students with particular learning style preferences and their performance on the Test of Understanding Graphs-Kinematics. Results of the statistical analyses reveal no significant relationship between learning style and student ability to interpret kinematics graphs as measured by the Test of Understanding Graphs-Kinematics. The results presented in Chapter 4 suggest that student learning style preferences as measured by the Productivity Environmental Preference Survey do not significantly affect performance on the Test of Understanding Graphs-Kinematics.

Differences in the visual aspects of the instructional techniques were most pronounced. The interactive digital video activities performed by students in the treatment group were highly visual. Data analysis involved viewing the motion of an object on the computer screen simultaneously with the corresponding kinematics graphs. However, the results of this study show that no significant relationship exists between any of the learning style elements assessed and mean scores on the Test of Understanding Graphs-Kinematics.

The post-lab activities were another measure of student ability to interpret motion graphs. Results of the post-lab activities reveal that students in the treatment group were more successful in drawing and interpreting graphs of motion that closely paralleled the motion they had observed during the laboratory session. This suggests that the visual nature of the laboratory exercises was a contributing factor to students' success. However, students in both instructional groups experienced similar levels of difficulty when asked to draw and interpret graphs of motion that deviated from what they had observed in the laboratory. This result suggests that the visual nature of the interactive digital video activity does not contribute to enhanced performance on graphical analysis tasks that deviate from what was observed any more than the traditional experience does.

Gender Effects

Results of the ANCOVA indicate a significant difference [$\underline{F}(1, 42) = 4.15$, $\underline{p} = .048$] exists on mean scores on the Test for Understanding Graphs-Kinematics between males and females after adjusting for differences in SAT scores and course grades. Upon adjusting for SAT scores and course grades, the mean score on the Test of Understanding Graphs-Kinematics was 12.77 for males 10.18 for females.

In an earlier study, Beichner (1994) also reported a significant difference between mean scores for males and females on the Test of Understanding Graphs-Kinematics. He reported a mean score of 9.5 for males and 7.2 for females [$t(491) = 5.66$, $\underline{p} < .01$]. A direct comparison cannot be made in terms of the magnitude of the mean scores reported by Beichner and the mean scores reported in this study due to differences in treatments and teaching styles employed by each investigator. However, the importance of these results lies in the fact that gender differences were observed in both studies.

Although direct comparisons cannot be made, the mean scores on the Test of Understanding Graphs-Kinematics were higher for students in this study than for those reported in Beichner's study. Although his students had not received any special instructional treatments, they had been exposed to traditional kinematics instruction prior to taking the Test of Understanding Graphs-Kinematics. Beichner also compared scores for students in trigonometry- and calculus-based physics classes to students in high school physics classes and found no significant difference between their mean scores on the Test of Understanding Graphs-Kinematics. The students in the current study were enrolled in a one-semester, algebra-based course for non-science majors. Even though these students most likely did not have as strong a mathematics background as students in Beichner's study, they were exposed to different instructional treatments prior to taking the Test for Understanding Graphs-Kinematics. The reported differences in mean scores between students in the two studies could be attributed to differences in instructional treatments and/or differences in teaching styles employed.

Table 13. TUG-K Scores by Instructional Group and by Gender

Instructional Group	Gender	Mean Score
Control	Males	13.50
Control	Females	9.52
Treatment	Males	12.04
Treatment	Females	10.85

For discussion purposes, Table 13 is presented which shows mean scores on the Test of Understanding Graphs-Kinematics displayed by instructional group and by gender. Instructional treatment was not found to be statistically significant. However, the overall differences in mean scores on the Test for Understanding Graphs-Kinematics between males and females were found to be statistically significant. Table 13 shows that the males in each group have higher mean scores on the Test for Understanding Graphs-Kinematics than the females.

TUG-K: Gender Issues Raised

Research on standardized tests (i.e. SAT, GRE, LSAT, etc...) and their relationship to gender have been widely reported in the literature (AAUW Report "How

Schools..." 1992; Sadker & Sadker, 1994; Sadker, Sadker & Long, 1989). The American Association of University Women Educational Foundation commissioned a report entitled How Schools Shortchange Girls (AAUW, 1992). In this document, results of studies in various areas including sex and gender bias in testing are presented. SAT scores are often used as a powerful criteria for admission of a student into a university. In addition, SAT scores are often used to predict a student's college success as defined by first year grades. Within this document it was suggested that "... SAT scores ... underpredict women's grades and overpredict men's. Young women tend to receive higher college grades than young men with the same SAT scores" (p. 56).

The results presented in the current study suggest that after controlling for differences in student ability levels as measured by SAT scores and course grades, a statistically significant difference exists on mean scores on the Test of Understanding Graphs-Kinematics based on gender. Instructional treatment was not found to be significantly related to mean scores on the Test of Understanding Graphs-Kinematics. The interaction between treatment and gender was also not significant. In addition, none of the learning style covariates tested were significantly related to mean scores on the test. Hence, the observed differences in mean scores on the Test of Understanding Graphs-Kinematics between males and females are most likely not due to differences in instructional methods or individual learning styles. One explanation for this difference is that a gender bias may be inherent in the Test of Understanding Graphs-Kinematics. Additional studies are needed to further investigate this noted gender difference.

Learning Styles and Instructional Techniques

Results of the statistical analyses performed indicate that no significant difference exists between learning styles, instructional techniques and performance on the Test of Understanding Graphs-Kinematics. Results of the Productivity

Environmental Preference Survey suggest slight differences in preferences between students in each group. However, since tests of statistical significance show no difference in mean scores on the Test of Understanding Graphs-Kinematics when learning style is treated as a covariate, firm conclusions regarding learning styles as noted in Chapter 4 cannot be drawn. Furthermore, the number of students expressing strong preferences within a given learning style element is quite small, again making the noted differences difficult to interpret.

The laboratory activities required students to make use of all the modality elements (i.e. auditory, visual, tactile, and kinesthetic). Results revealing modest differences in student learning style preferences between groups and between males and females were noted in Chapter 4 for the visual, tactile, kinesthetic, motivation and structure elements.

Activities performed by students in both groups included a comparable tactile component. Students in both groups handled laboratory equipment. Graphical analysis activities for students in the treatment group required the use of a computer. Students in the control group performed the graphical analyses by hand. Although the methods of analyses were different, they were similar in that they required students to do a comparable amount of work with their hands. However, differences in learning style scores on the tactile element were not significantly related to mean scores on the Test for Understanding Graphs-Kinematics. These results suggest that students' preferences on the tactile element did not contribute significantly to their performance on the Test for Understanding Graphs-Kinematics.

Labs were similar in the kinesthetic aspect as well. The *Freefall* laboratory may have had a somewhat higher kinesthetic element to it as students were active as they were dropping their balls and collecting their data with a video camera. Students in the treatment group were not as actively involved with the collection of data. The *Projectile*

Motion laboratories demanded that all students move around and interact with the equipment, so there were essentially no kinesthetic differences between activities performed by each group.

Differences in the visual aspects of activities performed by each group were the most pronounced. The laboratory activities performed by the treatment group had a stronger visual component than did the activities performed by the control group. Students in the treatment group spent a considerable amount of time analyzing their captured video and viewing graphs of the objects' motion on the computer screen. Although students in the treatment group were more successful responding to graphical interpretation questions that paralleled the motion they had observed during the laboratory, students in both groups had similar difficulties responding to questions that related to a motion that was different from what they had observed.

This study did not reveal any statistically significant relationships between mean scores on the Test of Understanding Graphs-Kinematics and student learning style preferences as measured by the Productivity Environmental Preference Survey. Thus, student learning style preferences do not appear to either enhance or detract from student ability to interpret kinematics graphs.

Relationship Between Gender and Learning Style Results Presented

Research conducted by Dunn (1996) regarding learning styles and gender suggested some documented differences between males and females. For example, male students tend to be more visual, tactile, and kinesthetic than females. In addition, males often need more mobility in an informal environment than do females. Males often tend to be more nonconforming and peer-motivated than females. On the other hand, more females tend to be auditory, conforming, and authority-oriented. Pizzo, Dunn, & Dunn (1990) reported that females tend to need significantly more quiet while learning than do males. Marcus (1977) reported that females tend to be more self-motivated and conforming than males.

Inspection of the results presented in this study suggests that more females (both groups) had auditory preferences than males. This result parallels ones reported in the literature. However, the laboratory activities performed by each group had similar auditory components. Therefore, the fact that more females had auditory preferences than males in this study, has little bearing on the results. Further inspection of the results show that more males than females have tactile preferences. Again, this parallels results presented in the literature. For the visual and kinesthetic categories the differences between males and females was less pronounced. In fact, more females than males in both groups displayed kinesthetic preferences. This result is inconsistent with the results presented by Pizzo, Dunn, & Dunn (1990). The relatively small number of students with preferences in these categories must be noted with caution. Further study is warranted to analyze learning style preferences by gender.

Student Attitude and Motivation

Considerable research was presented in the literature review which suggested that students are more motivated to learn and have more positive attitudes toward learning when their instruction involves some form of multimedia technique (Lamb, 1992; Thornton, 1987; Wilson, 1994; Zollman, 1996; Zollman and Fuller, 1994). However, the question remains as to whether increased student attitudes and motivation toward learning physics can lead to enhanced learning gains.

Results obtained in this study from observation of students as they performed each of the laboratory activities suggested that students in both instructional groups had positive attitudes toward the learning tasks. Motivational levels were also observed to be high for students in both groups. However, the observations revealed that student motivation toward the learning tasks was somewhat higher for students whose laboratory instruction included interactive digital video techniques. This conclusion was reached based on the fact that students using the interactive digital video tool appeared to be more motivated to repeat the analyses of their data than were students using more traditional laboratory techniques.

Video tapes were also made of each laboratory session. Results obtained from the analysis of the video tapes further suggested that students whose instruction included interactive digital video techniques displayed a slightly higher level of motivation toward repeating the analysis of their data than did students whose instruction involved more traditional techniques. Students in the treatment group were able to easily reload their video clips and repeat their analysis.

No evidence exists which suggest that the Hawthorne effect was present among students participating in this study. Students in both groups displayed positive attitudes and high levels of motivation toward the learning tasks. Certainly students were aware of the fact that instructional methods were varied for the two laboratory activities; however, none of the observations support a conclusion that the Hawthorne effect was present. This was most likely due to the fact that students were aware that everyone was required to submit the same written laboratory report. In addition, no evidence exists to support any form of "compensatory rivalry" between students instructed using traditional techniques and those instructed using interactive digital video techniques.

Suggestions for Further Research

This study was conducted within a laboratory setting. Future studies could involve analysis of interactive video techniques in both the classroom as well as the laboratory setting as they relate to student understanding of various topics in physics.

Future studies involving multimedia tools could assess learning gains in other topics covered in a typical physics course for non-science majors.

Comparison studies could be done using the techniques developed in this study to assess the role that other multimedia techniques may play in terms of student understanding of a variety of kinematics concepts as presented graphically. For example, there are various commercially available graphical analysis packages (such as *VideoPoint* and *VideoGraph*) that could be used to facilitate assessment of student learning of kinematics concepts through graphical interpretation and analysis.

The use of multimedia tools is thought to help students, particularly novice learners of physics, overcome cognitive difficulties associated with learning kinematics concepts. The assessment of learning gains is of critical importance. So often in research studies, the learning tools are assessed rather than the learning gains that are made possible as a result of the multimedia tools. Thus, the assessment of learning gains must continue to be measured using appropriate techniques.

The ability to draw and interpret graphs is important in kinematics as well as in other topics presented in a typical introductory physics course. Future studies could be designed that would allow students more opportunity to work with graphs throughout an entire course. Repeated exposure to graphical analysis techniques over a broad range of topics would add reinforcement and may lead to more pronounced learning gains.

The use of multimedia tools may lead to increased learner control over the overall learning experience. The increase in learner control is thought to lead to increased motivation and to increased learning gains. Additional studies need to be conducted to determine which aspects of learner control are motivating for students. Further, assessment tools need to be designed in order to determine if increased motivation can be translated into increased learning gains. Future studies could also address the issue of student interest and motivation versus student understanding.

Additional studies are also needed which would place emphasis on the assessment of learning gains using appropriate techniques following instruction that made use of interactive digital video and other multimedia tools within other areas of the introductory physics curriculum. Assessment tools need to specifically address learning gains that could be attributed to the use of the multimedia tools, rather than on the assessment of the learning tools themselves. Continued emphasis on the development of a theoretical framework specific to the analysis of the multiple attributes of these multimedia tools is recommended.

Additional studies involving multimedia tools and learning styles are warranted. In this study, no attempt was made to assign students to laboratory groups based on specific learning style preferences. A future study could be designed in which students were assigned to laboratory groups and activities based on their learning style preferences. Learning gains could be measured using appropriate tools to determine whether matching students' preferences to a specific activity would lead to enhanced understanding.

A future study could also address other learning style preferences as measured by the Productivity Environmental Preference Survey as they relate to learning gains. For example, other learning style elements such as time of day, persistence and preference to working alone or in a group are of interest to address, particularly since laboratory activities are performed in a group environment.

A gender issue was raised regarding the noted differences in performance between males and females on the Test of Understanding Graphs-Kinematics. One explanation for the differences is a potential gender bias inherent in the Test of Understanding Graphs-Kinematics. Additional studies are needed to further explore the reasons for these noted differences.

Additional gender issues were raised in this study regarding differences in learning styles. Some differences in learning style preferences between males and females were noted in this study. A future study could be designed to further address learning styles by gender as they relate to learning gains.

Finally, this study suggests that a limited number of instructional treatments involving interactive video do not lead to significant learning gains. A future study could include the measurement of learning gains when a larger number of instructional treatments are interspersed throughout the entire curriculum.

Conclusions

Based on the results obtained in this study, the following conclusions are offered.

1. Laboratory instructional treatment (interactive digital video versus traditional) was not a significant factor upon students' understanding of kinematics concepts as measured by mean scores on the Test of Understanding Graphs-Kinematics.
2. Learning style differences among students cannot be used to explain statistically differences in students' understanding of kinematics concepts as evidenced by mean scores on the Test of Understanding Graphs-Kinematics.
3. Results of the statistical analysis show a significant difference in mean scores on the Test of Understanding Graphs-Kinematics exists after adjusting for SAT scores and course grades between males and females. This result suggests a possible gender bias inherent in the Test of Understanding Graphs-Kinematics.
4. Regression analysis revealed that more variance in mean scores on the Test of Understanding Graphs-Kinematics can be explained with SAT scores for females than for males. In addition, more variance in mean scores on the Test of Understanding Graphs-Kinematics can be explained with course grades for females than for males.

5. Although students in both instructional groups displayed positive attitudes toward the learning tasks at hand, students in the interactive digital video laboratory treatment group showed more motivation to repeat the analyses than students in the traditional laboratory group. Hence, students in the treatment group spent more time analyzing their data and discussing their results with one another.

6. Students performing the interactive digital video laboratories could respond more effectively to post-lab questions that pertained specifically to the learning task they had performed than could students performing the more traditional laboratories.

7. Students in both instructional groups displayed similar difficulties when confronted with graphical interpretation post-lab questions that deviated slightly from the tasks they had performed in the laboratory.

Implications and Recommendations

This study provides evidence of the effect of laboratory instruction that utilized interactive digital video techniques as compared to traditional laboratory techniques on students' ability to understand kinematics concepts through analysis of motion graphs. The Test of Understanding Graphs-Kinematics was used as one measure of students' ability to interpret motion graphs. Although mean scores for students whose instruction involved interactive digital video techniques were slightly higher than for students whose instruction involved traditional techniques, the difference in mean scores was not statistically significant.

In a study involving interactive videodisc instruction with high school students, Brungardt and Zollman (1995) utilized four different treatments involving mechanics. For each exercise students in the real-time group observed graphs of various objects' motion simultaneously with the motion of on a video screen. Students in the delay-time group observed the same motion graphs several minutes after the motion of the object.

They reported no significant difference between mean scores on the *Questions on Linear Motion* section of the *Tools for Scientific Assessment* instrument following the instructional treatments. The current study involved two instructional treatments, and no statistical significance was found between instructional groups based on mean scores on the Test of Understanding Graphs-Kinematics after adjusting for SAT scores and course grades. One recommendation is that additional exposure to these interactive learning tools is needed to assess learning gains more effectively. This exposure should be interspersed throughout the semester for a wider range of topics.

The results of this study do not suggest a direct connection between student learning styles and the instructional technique used in this study. Two additional factors must be acknowledged here. The first factor is the relatively small number of students with preferences in the high and low categories of the Productivity Environmental Preference Survey. To make a firm connection between learning styles and instructional technique, a larger sample size could be employed. Because of the many components in an individual's learning style, large sample sizes cannot exist within each learning styles element unless the class size is very large. Hence, the number of students with learning style preferences in particular categories of interest was quite small, even though the overall number of students in the study was reasonably large (n = 68).

A second factor which should be considered is the limited number of treatments given to students participating in this study. Students participating in this study performed a total of six laboratory exercises during the semester. Two of these exercises involved the use of interactive digital video. Increasing the number of instructional treatments may lead to enhanced learning gains.

The results of this study showed a statistically significant difference on the Test of Understanding Graphs-Kinematics between males and females after adjusting for SAT scores and course grades. Similar results have surfaced in other research which analyzed gender effects and student performance on standardized tests. Although some differences between learning styles of males and females have been noted. they cannot be used to entirely explain these results. A larger sample size would be needed in order to form a conclusion based on gender. learning styles and student performance on the Test of Understanding Graphs-Kinematics. The results of this study suggest that a potential gender bias exists in the Test of Understanding Graphs-Kinematics. A future study could be designed to address the gender difference noted here.

Further analyses of the results of this study suggested that students whose laboratory instruction involved interactive digital video techniques were more motivated to perform repeated analyses of their results. Hence. these students spent. on average. more time working with the data they had collected than students in the traditional laboratories. However, much of the extra time spent by students in this study were on procedural rather than conceptual issues, particularly during the first laboratory activity. Once students had performed the first activity. they were not as focused on the procedure issues and spent more time on conceptual analyses. Therefore a recommendation for future studies would be to pay more attention to this time on task factor.

Applications for Teaching

Results presented in this study offer a broad range of applications for teaching. Some students thrive in a traditional lecture system. These students most likely have been able to conform to the traditional system, regardless of their learning styles. However. a considerable amount of research was presented in the literature review that suggested that the traditional lecture system essentially isolates a large number of students. Research was presented that suggested that assessment of learning styles is a necessary first step toward designing a teaching/learning environment better suited to a diverse clientele. Assessment of learning styles is particularly important when class sizes are large. Maintaining a single style of teaching will certainly lead to isolation of a large number of students. Hence, modification of teaching strategies to accommodate better a wide range of learning styles is critical in terms of enhancing the learning process for many students. As multimedia instructional tools are developed. the relationship between the pedagogical advantages of these tools and student learning styles can be addressed.

The attention paid in this study to student understanding of kinematics concepts through graphical interpretation following instruction that utilized interactive digital video techniques has broad applications. A strong component of this study focused on students' ability to interpret motion graphs. Graphical analysis is important in both physics and mathematics teaching. Hence, the results presented regarding student ability to interpret motion graphs may be extended to other topics in physics and other teaching domains, such as mathematics.

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ENDNOTES

[1] Dunn. R. Dunn. K.. & Price, G. E. (1991). *Productivity Environmental Preference Survey* (PEPS). Center for the Study of Learning and Teaching Styles, St. John's University, Jamaica, NY 11439. Reprinted by permission.

[2] From *Teaching Secondary Students Through Their Individual Learning Styles: Practical Approaches for Grades 7 -12* (p. 4) by R. Dunn and K. Dunn. 1993. Boston: Allyn and Bacon. Copyright 1993 by Allyn and Bacon. Reprinted by permission.

APPENDIX A

THE TEST FOR UNDERSTANDING GRAPHS - KINEMATICS

Test of
Understanding
Graphs–
Kinematics *version 2.6*

Instructions

Wait until you are told to begin, then turn to the next page and begin working. Answer each question as accurately as you can. There is only one correct answer for each item. Feel free to use a calculator and scratch paper if you wish.

Use a #2 pencil to **record your answers** on the computer sheet, but please **do not write in the test booklet.**

You will have approximately one hour to complete the test. If you finish early, check over your work before handing in both the answer sheet and the test booklet.

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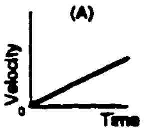
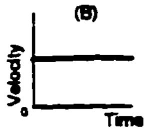
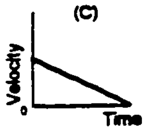
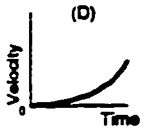
Beichner @ NCSU.edu

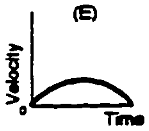
❶ Velocity versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest change in position during the interval?





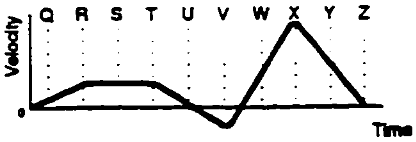






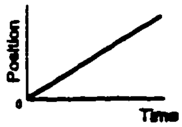
● When is the acceleration the most negative?

(A) R to T
(B) T to V
(C) V
(D) X
(E) X to Z



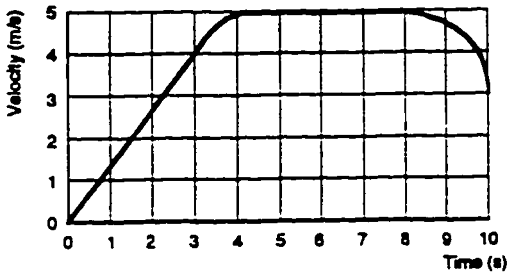
● To the right is a graph of an object's motion. Which sentence is the best interpretation?

(A) The object is moving with a constant, non-zero acceleration.
(B) The object does not move.
(C) The object is moving with a uniformly increasing velocity.
(D) The object is moving at a constant velocity.
(E) The object is moving with a uniformly increasing acceleration.



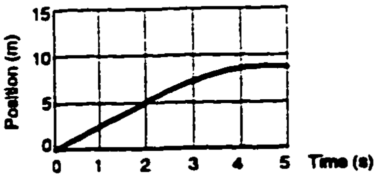
● An elevator moves from the basement to the tenth floor of a building. The mass of the elevator is 1000 kg and it moves as shown in the velocity-time graph below. How far does it move during the first three seconds of motion?

(A) 0.75 m
(B) 1.33 m
(C) 4.0 m
(D) 6.0 m
(E) 12.0 m



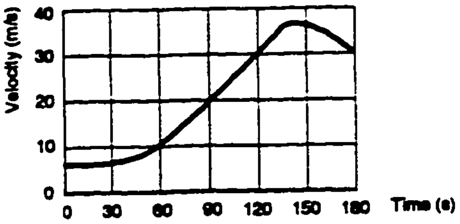
● The velocity at the 2 second point is:

(A) 0.4 m/s
(B) 2.0 m/s
(C) 2.5 m/s
(D) 5.0 m/s
(E) 10.0 m/s



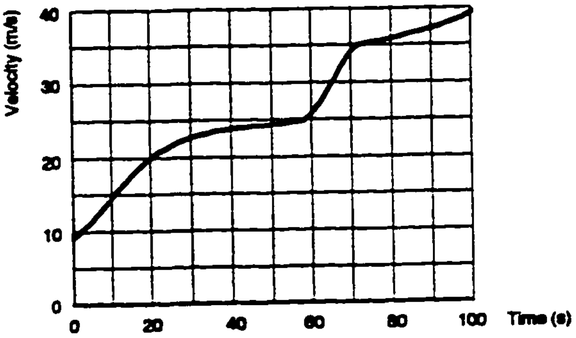
● This graph shows velocity as a function of time for a car of mass 1.5 x 10^3 kg. What was the acceleration at the 90 s mark?

(A) 0.22 m/s²
(B) 0.33 m/s²
(C) 1.0 m/s²
(D) 9.8 m/s²
(E) 20 m/s²

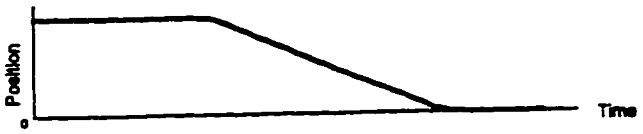


● The motion of an object traveling in a straight line is represented by the following graph. At time = 65 s, the magnitude of the instantaneous acceleration of the object was most nearly:

(A) 1 m/s²
(B) 2 m/s²
(C) +9.8 m/s²
(D) +30 m/s²
(E) +34 m/s²



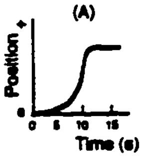
● Here is a graph of an object's motion. Which sentence is a correct interpretation?



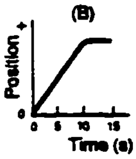
(A) The object rolls along a flat surface. Then it rolls forward down a hill, and then finally stops.
(B) The object doesn't move at first. Then it rolls forward down a hill and finally stops.
(C) The object is moving at a constant velocity. Then it slows down and stops.
(D) The object doesn't move at first. Then it moves backwards and then finally stops.
(E) The object moves along a flat area, moves backwards down a hill, and then it keeps moving.

⑨ An object starts from rest and undergoes a positive, constant acceleration for ten seconds. It then continues on with constant velocity. Which of the following graphs correctly describes this situation?

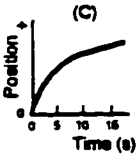
(A)



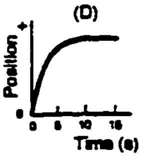
(B)



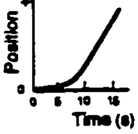
(C)



(D)

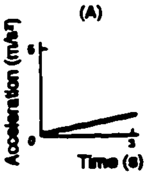


(E)



❶⓪ Five objects move according to the following acceleration versus time graphs. Which has the smallest change in velocity during the three second interval?

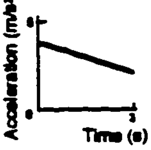
(A)



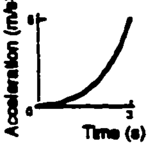
(B)

(C)

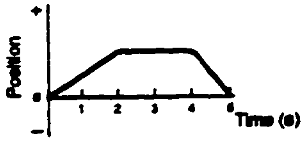
(D)



(E)

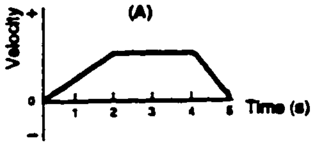


❶❶ The following is a position-time graph for an object during a 5 s time interval.

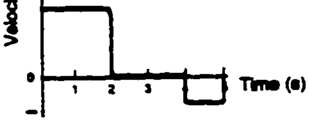


Which one of the following graphs of velocity versus time would best represent the object's motion during the same time interval?

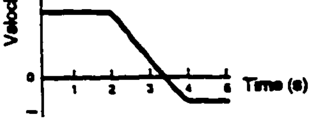
(A)



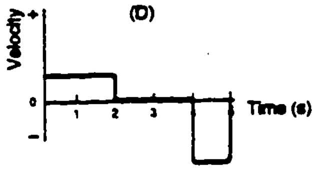
(B)



(C)

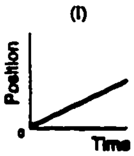


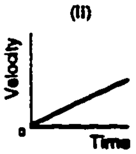
(D)

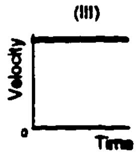


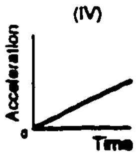
(E)

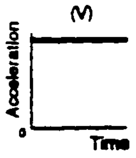
❶❷ Consider the following graphs, noting the different axes:







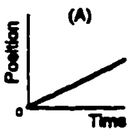


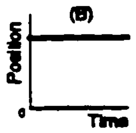


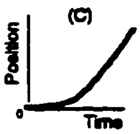
Which of these represent(s) motion at constant velocity?

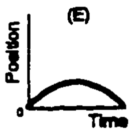
(A) I, II, and IV
(B) I and III
(C) II and V
(D) IV only
(E) V only

❶❸ Position versus time graphs for five objects are shown below. All axes have the same scale. Which object had the highest instantaneous velocity during the interval?

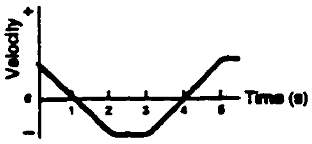




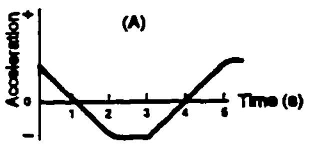


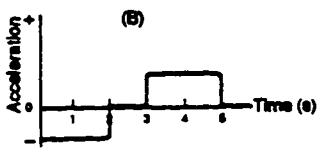


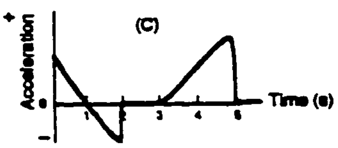
❶❹ The following represents a velocity-time graph for an object during a 5 s time interval.

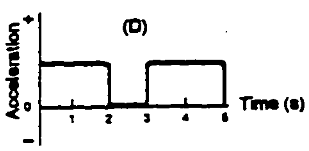


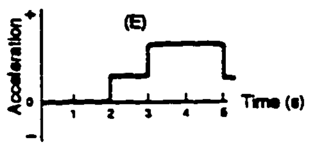
Which one of the following graphs of acceleration versus time would best represent the object's motion during the same time interval?



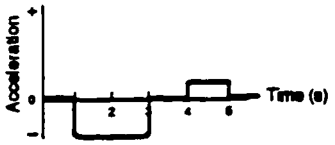




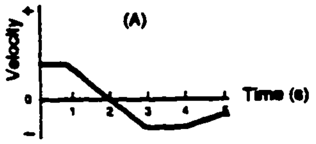


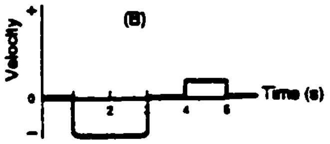


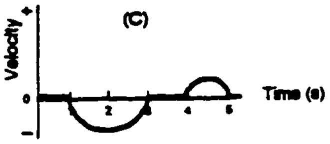
❶❼ The following represents an acceleration graph for an object during a 5 s time interval.

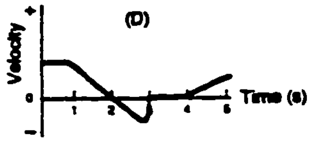


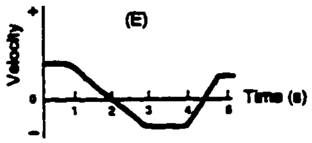
Which one of the following graphs of velocity versus time would best represent the object's motion during the same time interval?



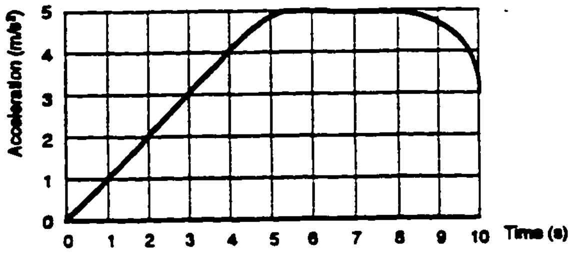








[illegible] An object moves according to the graph below:

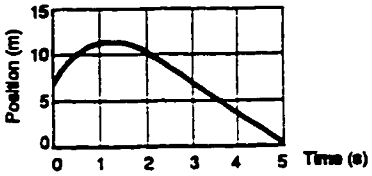


The object's change in velocity during the first three seconds of motion was:

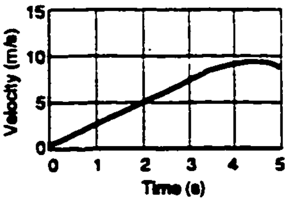
(A) 0.66 m/s (B) 1.0 m/s (C) 3.0 m/s (D) 4.5 m/s (E) 9.8 m/s

❶❼ The velocity at the 3 second point is about:

(A) − 3.3 m/s
(B) − 2.0 m/s
(C) − .67 m/s
(D) 5.0 m/s
(E) 7.0 m/s



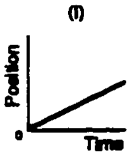
⑮ If you wanted to know the distance covered during the interval from t = 0 s to t = 2 s, from the graph below you would:



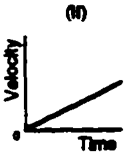
(A) read 5 directly off the vertical axis.
(B) find the area between that line segment and the time axis by calculating (5x2)/2.
(C) find the slope of that line segment by dividing 5 by 2.
(D) find the slope of that line segment by dividing 15 by 5.
(E) Not enough information to answer.

⑲ Consider the following graphs, noting the different axes:

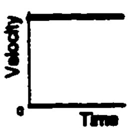
(I)



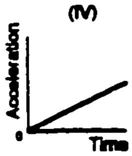
(II)



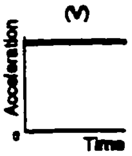
(III)



(IV)



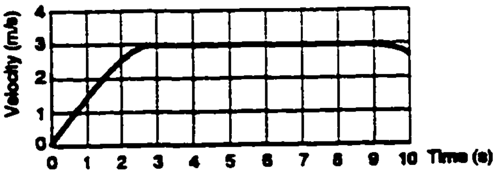
(V)



Which of these represent(s) motion at constant, non-zero acceleration?

(A) I, II, and IV
(B) I and III
(C) II and V
(D) IV only
(E) V only

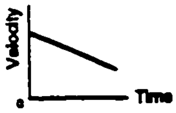
⑳ An object moves according to the graph below:



How far does it move during the interval from t = 4 s to t = 8 s ?

(A) 0.75 m (B) 3.0 m (C) 4.0 m (D) 8.0 m (E) 12.0 m

㉑ To the right is a graph of an object's motion. Which sentence is the best interpretation?



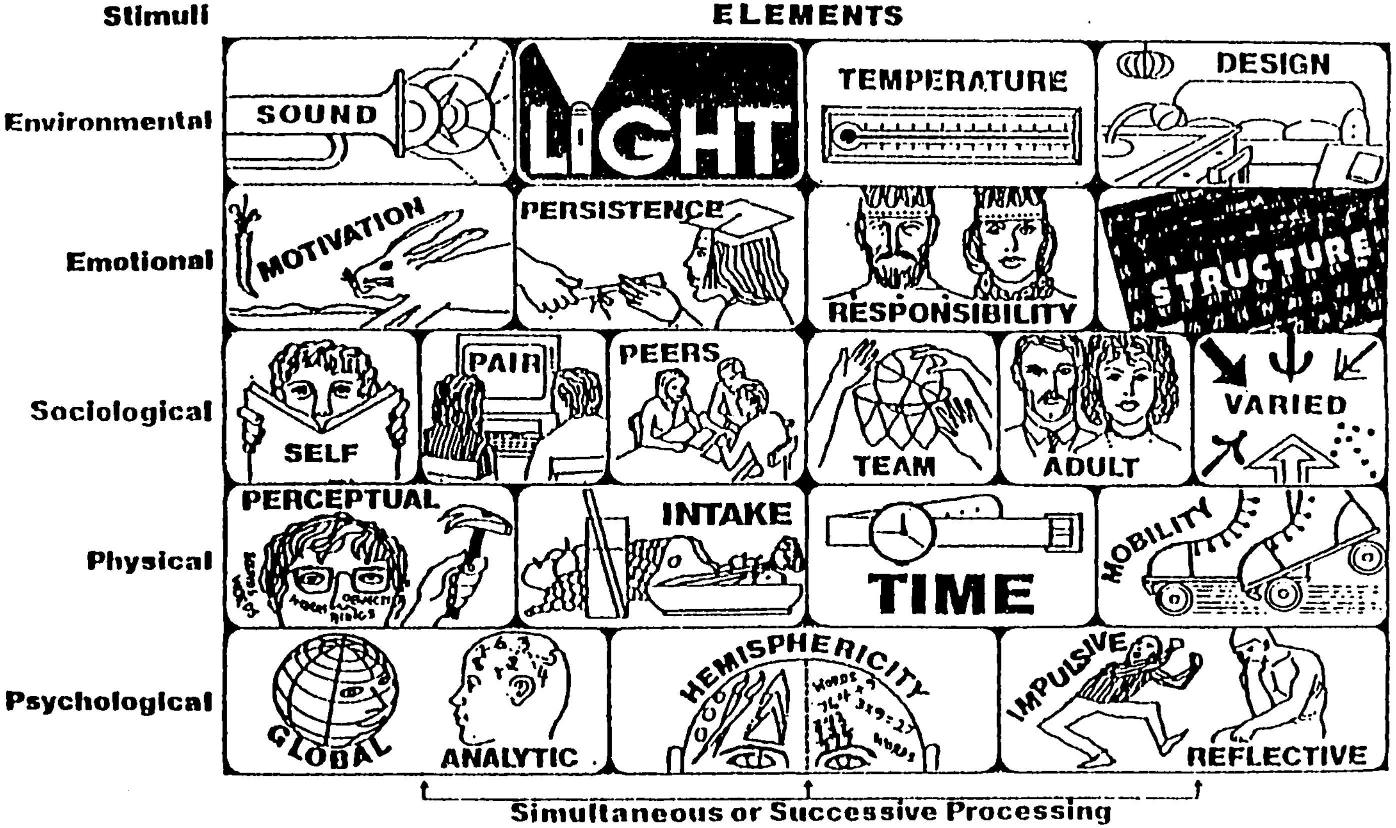
(A) The object is moving with a constant acceleration.
(B) The object is moving with a uniformly decreasing acceleration.
(C) The object is moving with a uniformly increasing velocity.
(D) The object is moving at a constant velocity.
(E) The object does not move.

APPENDIX B

THE DUNN AND DUNN LEARNING STYLE MODEL

LEARNING STYLES MODEL

DESIGNED BY
DR. RITA DUNN
DR. KENNETH DUNN



APPENDIX C

THE PRODUCTIVITY ENVIRONMENTAL PREFERENCE SURVEY

PRODUCTIVITY ENVIRONMENTAL PREFERENCE SURVEY Dunn, Dunn and Price

FORM [illegible]

Major or Occupation

PRINT INSIDE BOXES IN AREA ONLY

Copyright © [illegible] Price Systems, Inc.

USE A NO. 2 PENCIL. DO NOT FOLD OR STAPLE

NAME LAST NAME FIRST

GRADE OR EDUCATION

DO NOT MARK HERE

SEX FEMALE ○ MALE ○

BIRTHDAY YEAR MONTH

SPECIAL CODES

IDENTIFICATION NUMBER

Write your name, sex, and birthdate in the space provided. Blacken the bubbles below each of the boxes you filled out.

Read each statement and decide to what extent you would agree or disagree with that statement if you had something new or difficult to learn. Mark (SD), if you strongly disagree, or (D), disagree, or (U), uncertain, or (A), agree, or (SA), strongly agree, as the response that best describes how you feel most of the time. Give your immediate or first reaction to each question. Please answer all the questions on both sides of form.

1. I prefer working in bright light. .... (SD) (D) (U) (A) (SA)
2. I like to work alone. .... (SD) (D) (U) (A) (SA)
3. It is easy for me to concentrate late at night. .... (SD) (D) (U) (A) (SA)
4. I like to draw or use diagrams when I work. .... (SD) (D) (U) (A) (SA)
5. I often have to be reminded to complete certain tasks or assignments. .... (SD) (D) (U) (A) (SA)
6. The one job I like doing best, I like to do with an expert in the field. .... (SD) (D) (U) (A) (SA)
7. I can think better lying down than sitting. .... (SD) (D) (U) (A) (SA)
8. I prefer cool temperatures when I need to concentrate. .... (SD) (D) (U) (A) (SA)
9. I like to block out noise or sound when I work. .... (SD) (D) (U) (A) (SA)
10. People keep reminding me to complete my work. .... (SD) (D) (U) (A) (SA)
11. It is difficult for me to concentrate when I am warm. .... (SD) (D) (U) (A) (SA)
12. The one job I like doing best, I do with two or more people. .... (SD) (D) (U) (A) (SA)
13. I prefer to work or read where the lights are shaded. .... (SD) (D) (U) (A) (SA)
14. When I concentrate I like to sit on a soft chair or couch. .... (SD) (D) (U) (A) (SA)
15. I usually finish what I start. .... (SD) (D) (U) (A) (SA)
16. The things I remember best are the things that I hear. .... (SD) (D) (U) (A) (SA)
17. I enjoy tasks that allow me to take breaks. .... (SD) (D) (U) (A) (SA)
18. I can work more effectively in the afternoon than in the morning. .... (SD) (D) (U) (A) (SA)
19. I like to "snack" when I'm concentrating. .... (SD) (D) (U) (A) (SA)
20. When I have a lot of work to do I like to work with several colleagues. .... (SD) (D) (U) (A) (SA)
21. Noise or extraneous sound usually keeps me from concentrating. .... (SD) (D) (U) (A) (SA)
22. I often forget to do the things I've said I would do. .... (SD) (D) (U) (A) (SA)
23. I take lots of notes in a lecture, to help me remember. .... (SD) (D) (U) (A) (SA)
24. I like to work or analyze an assignment with another individual. .... (SD) (D) (U) (A) (SA)
25. I prefer cool temperatures when I'm working. .... (SD) (D) (U) (A) (SA)
26. The one job I like doing best, I do with several people. .... (SD) (D) (U) (A) (SA)
27. I concentrate best in the late afternoon. .... (SD) (D) (U) (A) (SA)
28. The things I remember best are the things that I read. .... (SD) (D) (U) (A) (SA)
29. I usually complete tasks that I start. .... (SD) (D) (U) (A) (SA)
30. I can concentrate better when I sit up rather than when I recline. .... (SD) (D) (U) (A) (SA)
31. I like to learn or work with a person in authority. .... (SD) (D) (U) (A) (SA)
32. I work best early in the morning. .... (SD) (D) (U) (A) (SA)
33. I get a lot done when I work on my own. .... (SD) (D) (U) (A) (SA)
34. When I work I turn all the lights on. .... (SD) (D) (U) (A) (SA)
35. I prefer that others share responsibility for a task we're doing. .... (SD) (D) (U) (A) (SA)
36. I really enjoy television. .... (SD) (D) (U) (A) (SA)
37. I like either a teacher or supervisor to outline tasks I have to complete. .... (SD) (D) (U) (A) (SA)
38. I like to sit on a straight-back chair when I concentrate. .... (SD) (D) (U) (A) (SA)
39. I work or study best by myself. .... (SD) (D) (U) (A) (SA)
40. I can remember things best when I study them in the evening. .... (SD) (D) (U) (A) (SA)
41. I remember best the things I read in a book or magazine. .... (SD) (D) (U) (A) (SA)
42. I always finish tasks that I start. .... (SD) (D) (U) (A) (SA)
43. If I have to learn something new, I prefer to learn about it by hearing a record, tape or lecture. .... (SD) (D) (U) (A) (SA)
44. I am most alert in the evening. .... (SD) (D) (U) (A) (SA)

45. The one job I like doing best, I do with a group of people. .... SD D U A SA
46. I am uncomfortable when I work or try to study in a warm room. .... SD D U A SA
47. I prefer to have teachers or supervisors set deadlines for my work. .... SD D U A SA
48. I like to eat while I'm concentrating. .... SD D U A SA
49. I prefer completing one thing before I start something else. .... SD D U A SA
50. It is difficult for me to start a new task before I finish the task I am doing. .... SD D U A SA
51. I really enjoy movies. .... SD D U A SA
52. I have to be reminded to do things I've said I would do. .... SD D U A SA
53. I work best when the lights are shaded. .... SD D U A SA
54. I prefer that persons in authority stay away until I have completed my work. .... SD D U A SA
55. I keep trying to accomplish a task even if it appears that I may not succeed. .... SD D U A SA
56. I like to learn about something new by hearing a tape or a lecture. .... SD D U A SA
57. I feel I am self-motivated. .... SD D U A SA
58. The one job I like doing best, I prefer doing alone. .... SD D U A SA
59. Eating something would distract me when I'm working. .... SD D U A SA
60. My performance improves if I know my work will be checked. .... SD D U A SA
61. I prefer to work with music playing. .... SD D U A SA
62. I stay at a task until it is finished, even if I don't like what has to be done. .... SD D U A SA
63. I learn best by being directly involved in what I am doing. .... SD D U A SA
64. I always do the best I can. .... SD D U A SA
65. I prefer to learn how to do a new task by actually doing it. .... SD D U A SA
66. I often read in dim light. .... SD D U A SA
67. If I have to learn something new, I like to learn about it by reading. .... SD D U A SA
68. I prefer someone else carefully outline how a task should be done. .... SD D U A SA
69. I would rather start work in the morning than in the evening. .... SD D U A SA
70. I constantly change positions in my chair. .... SD D U A SA
71. The things I remember best are the things that I hear. .... SD D U A SA
72. I like my instructor(s) or supervisor(s) to recognize my efforts. .... SD D U A SA
73. I learn better by reading than by listening to someone. .... SD D U A SA
74. I get more done in the afternoon than in the morning. .... SD D U A SA
75. I can block out most sound when I work. .... SD D U A SA
76. I really like to build things. .... SD D U A SA
77. I prefer to work under a shaded lamp with the rest of the room dim. .... SD D U A SA
78. I choose to eat, drink or chew only after I finish working. .... SD D U A SA
79. I remember things better when I study in the evening. .... SD D U A SA
80. If I have to learn something new, I like to learn about it by seeing a movie. .... SD D U A SA
81. I feel good when my spouse, colleague or supervisor praises me for doing well at my job. .... SD D U A SA
82. I prefer a cool environment when I try to study. .... SD D U A SA
83. It's difficult for me to block out sound (music, T.V., talking) when I work. .... SD D U A SA
84. I would rather learn by experience than by reading. .... SD D U A SA
85. I like being praised for a "job well done." .... SD D U A SA
86. It's difficult for me to sit in one place for a long time. .... SD D U A SA
87. I like to have something to drink when I work. .... SD D U A SA
88. I enjoy doing experiments. .... SD D U A SA
89. If a task becomes very difficult, I tend to lose interest in it. .... SD D U A SA
90. I like to learn new things. .... SD D U A SA
91. I can sit in one place for a long time. .... SD D U A SA
92. I can concentrate best in the evening. .... SD D U A SA
93. I prefer to study with someone who really knows the material. .... SD D U A SA
94. I often change my position when I work. .... SD D U A SA
95. I would work more effectively if I could eat while I'm working. .... SD D U A SA
96. If I can go through each step of a task, I always remember what I learn. .... SD D U A SA
97. I learn better when I read the instructions than when someone tells me what to do. .... SD D U A SA
98. I only begin to feel wide awake after 10:00 A.M. .... SD D U A SA
99. I often complete unfinished work on a bed or couch where I can recline. .... SD D U A SA
100. I often wear a sweater or jacket indoors. .... SD D U A SA

STOP

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APPENDIX D

INDIVIDUAL LEARNING STYLE FEEDBACK PROFILE

- PRODUCTIVITY ENVIRONMENTAL PREFERENCE SURVEY -

```
DATE:      07-18-1991                  INDIVIDUAL PROFILE                    GROUP NO.:     109

NAME:      HEIN TERESA          SEX:  F         YR. IN SCHOOL:              BIRTHDATE:       /
                                                                                          YRMO
GROUP IDENTIFICATION:   SOUTH DAKOTA ST       SPECIAL CODE:  123            ID. NO.:  504889550

                                       PREFERENCE SUMMARY

RAW    STANDARD
SCORE   SCORE     20       30            40           50           60          70        80
 20      62      1  Prefers Quiet          |     Noise Level        |-*-   Prefers Sound        1
 20      49      2    Prefers Dim          |       Light            |      Prefers Bright       2
 17      52      3    Prefers Cool         |     Temperature        |       Prefers Warm        3
 22      62      4  Prefers Informal       |       Design           |-*-   Prefers Formal       4
 25      63      5        Low              |     Motivation         | -*-       High          5
 20      58      6        Low              |     Persistent     -*- |           High          6
 31      60      7        Low              |     Responsible       -*-          High          7
 10      57      8  Does not Like          |      Structure   -*-   |          Wants          8
 16      43      9 Prefers Learning Alone  |  -*-    Peers          | Prefers Learning with   9
 16      63     10 Does not want Present   |  Authority Figures     | -*-  Wants Present     10
 18      63     11  Does not Learn in      |    Several Ways        | -*- Prefers Variety    11
 11      49     12   Does not prefer       |      Auditory          |          Prefers       12
 20      50     13   Does not prefer       |       Visual           |          Prefers       13
 16      60     14   Does not prefer       |      Tactile          -*-         Prefers       14
 19      60     15   Does not prefer       |    Kinesthetic        -*-         Prefers       15
 20      50     16   Does not prefer       |       Intake           |          Prefers       16
 34      61     17   Prefers Evening       |     Time of Day       -*-    Prefers Morning    17
  9      49     18   Does not prefer       |    Late*Morning        |          Prefers       18
  6      45     19   Does not prefer       |   -*-Afternoon         |          Prefers       19
 16      51     20   Does not prefer       |      Mobility          |          Prefers       20

                  20       30            40           50           60          70        80

                                                                              PROFILE NO.:  14
```

Interpretation of the Productivity Environmental Preference Survey

1. SOUND

For standard score of 60 or more, provide soft music, ear phones. conversation areas. or an open-work environment.

For standard score of 40 or less, establish silent areas; provide individual office alcoves with sound proofing; provide ear plugs to block sound, if necessary.

2. LIGHT

For standard score of 60 or more, place employee near window or under bright illumination; add table or desk lamps.

For standard score of 40 or less, create work spaces under indirect or subdued light away from windows; use dividers or plants to block or diffuse light.

3. WARMTH

For standard score of 60 or more, provide adequate warmth, enclosures, screens, supplemental heaters and placement in warmer areas; allow sweaters; suggest use of warm colors and textured materials.

For standard score of 40 or less, provide adequate air-conditioning, ventilation, and placement in cooler areas; suggest cool colors; permit short sleeved shirts, shorts, etc.

4. FORMAL/INFORMAL DESIGN

For standard score of 60 or more, create “formal” climate - rows of desks, straight chairs, walls having straight lines and simple designs, and direct lighting.

For standard score of 40 or more, provide “informal” climate - soft chairs and couches, pillows, some color, lounge furniture, and indirect lighting.

5. MOTIVATED/UNMOTIVATED

For standard score of 60 or more, encourage use of self-designed objectives, procedures and evaluation before the instructor or supervisor assesses effort; permit self-pacing and rapid achievement.

For standard score of 40 or less, design short-term, simple, uncomplicated assignments that require frequent discussions with the instructor or supervisor; provide several easily understood options based on the individual’s interests; experiment with short-range motivators and reinforcement; solicit self-developed goals and procedures: log results and progress; provide opportunities for success and achievement on cooperatively-designed objectives.

6. PERSISTENT

For standard score of 60 or more, design long-term assignments; provide supervision and assistance only when necessary; suggest when help may be obtained if necessary; praise at completion of assignment.

For standard score of 40 or less, provide short-term, limited assignments; check and log progress frequently; provide options based on individual's interests; experiment with short-range motivators and reinforcement; praise during process of successful completion of tasks; encourage self-design of short tasks; permit attention to multiple tasks simultaneously.

7. RESPONSIBLE

For standard score of 60 or more, begin by designing short-term assignments; as these are successfully completed, gradually increase their length and scope; challenge the individual at the level of his or her functional ability or slightly beyond.

For standard score of 40 or less, design short-term, limited assignments with only single or dual goals; provide acceptable options and frequent checking by the instructor or supervisor; directions should be simple and responsible colleagues should be placed in the immediate environment and on the same projects. Base assignments on interests and use interim praise or rewards during the successful completion of tasks or objectives. Explain why the tasks are important and speak collegially rather than authoritatively.

8. STRUCTURE

For standard score of 60 or more, be precise about every aspect of the assignment; permit no options; use clearly stated objectives in a simple form; list and itemize as many things as possible, leave nothing for interpretation; clearly indicate time requirements and the resources that may be used; required tasks should be indicated; as successful completion is evidenced, gradually lengthen the alternative procedures; gradually increase the number of options; establish specific working and reporting patterns and criteria as each task is completed.

For standard score of 40 or less, establish clearly stated objectives but permit choice of resources, procedures, time lines, reporting, checking, etc.; permit choice of environmental, sociological and physical elements; provide creative options and opportunities to grow and to stretch talents and abilities; review work at regular intervals but permit latitude for completion if progress is evident. Some employees may not prefer structure but require close supervision.

9. LEARNING ALONE/PEER-ORIENTED LEARNER

For standard score of 40 or less, encourage use of self-designed objectives. procedures and evaluations before the supervisor assesses effort; permit self pacing and achievement beyond department goals; encourage creativity when it is evidenced: such adults work well alone rather than on committees or in groups.

For standard score of 60 or more. pair or team this person with colleague-oriented or authority-oriented individuals that complement his/her sociological characteristics. e.g.. prefers to work with colleagues, is team-oriented with a small group. and so on. Encourage colleague meetings and planning; permit these individuals to evaluate each other individually and in groups; seek group suggestions and recommendations: use small-group training techniques.

10. AUTHORITY-ORIENTED LEARNER

For standard score of 60 or more. place these employees near appropriate instructors or supervisors and schedule numerous meetings among them; plan to visit and check work often; provide frequent feedback through the person's perceptual strengths.

For standard score of 40 or less, identify the person's sociological characteristics, and permit isolated achievement if self-oriented, worker groupings if colleague-oriented. or multiple options if learning in several ways is indicated.

11. SEVERAL WAYS

For standard score of 60 or more, provide opportunities for a variety of working patterns for the same employee, i.e., alone, with colleagues, with supervisors; use varied resources.

For standard score of 40 or less, permit the person to work in the sociological pattern most preferred. If none are strong, permit options. Recheck self-orientation and motivation. responsibility. and persistence. Utilize patterns and routines.

12. AUDITORY PREFERENCES

For standard score of 60 or more, use tapes, videotapes, records, radio, television. and precise oral directions when giving assignments, setting tasks, reviewing progress, using resources or for any aspect of the task requiring understanding, performance, progress, or evaluation.

For standard score of 40 or less, use resources prescribed under the perceptual preferences that are strong. If none are 60 or more, use several multisensory resources such as computers, videotapes, sound filmstrips, television, and tactual/kinesthetic materials. Suggest this person read and take notes before listening to lecture or audio management resources.

13. VISUAL PREFERENCES

For standard score of 60 or more, use pictures, filmstrips, computers, films, graphs, single concept loops, transparencies, diagrams, drawings, books, and magazines; provide resources that require reading and seeing, use programmed learning (if in need of structure) and written assignments and evaluations. These individuals should read the material before hearing a lecture.

For standard score of 40 or less, use resources prescribed under the perceptual preferences that are strong. If none are 60 or more, use several multisensory resources such as computers, videotapes, sound filmstrips, television, and tactual/kinesthetic materials. Suggest that this person listen to lecture and take notes before reading required materials.

14. TACTILE PREFERENCES

For standard score of 60 or more, use manipulative and three dimensional materials; resources should be touchable and movable as well as readable; allow these individuals to plan, demonstrate, report, and evaluate with models and other real objects; encourage them to keep written records.

For standard score of 40 or less, use resources prescribed under the perceptual preferences that are strong. If none are 60 or more, use several multisensory resources such as computers, video tapes, sound filmstrips, television, and real-life experiences such as visits, interviewing, building, designing, and so on. Note-taking and manipulatives will be less effective than readings and lectures.

15. KINESTHETIC PREFERENCES

For standard score of 60 or more, provide opportunities for real and active experiences for planning and carrying out objectives; site visits, seeing projects in action and becoming physically involved are appropriate activities for these individuals.

For standard score of 40 or less, use resources prescribed under the preferences that are strong. If none are 60 or more, use several multisensory resources such as computers, videotapes, sound filmstrips, television, and tactual/manipulative materials.

16. REQUIRES INTAKE

For standard score of 60 or more, provide frequent opportunities for nutritious food breaks, food at work station. beverages at desk, and so on.

For standard score of 40 or less, no special arrangements are needed.

17. EVENING/MORNING

For standard score of 60 or more, permit scheduling of difficult tasks in morning. Take advantage of the strongest time segment of the time energy curve for morning. If possible, allow self-scheduling before normal working hours if desired by the employee.

For standard score of 40 or less, permit scheduling of difficult tasks in evening. Take advantage of the strongest segment of the time energy curve for evening. If possible, allow self-scheduling after normal working hours if desired by employee. Flex-time self-scheduling will greatly enhance productivity for employees scoring above 60 in any of the areas related to time preferences.

18. LATE MORNING

For standard score of 60 or more, permit scheduling of difficult tasks in late morning. Take advantage of the strongest segment of the time energy curve for late morning.

For standard score of 40 or less, permit scheduling of difficult tasks in the strongest element of the time energy curve.

19. AFTERNOON

For standard score of 60 or more, permit scheduling of difficult tasks in afternoon. Take advantage of the strongest segment of the time energy curve for afternoon.

For standard score of 40 or less, permit scheduling of difficult tasks in the strongest segment of the time energy curve.

20. NEEDS MOBILITY

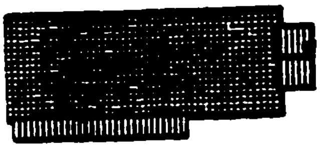
For standard score of 60 or more, provide frequent breaks, assignments that require movement to different locations, and schedules that build mobility into the work/learning pattern; require results, not immobility.

For standard score of 40 or less, provide stationary desk or work station where most of the individual's responsibilities can be completed without requiring excessive movement.

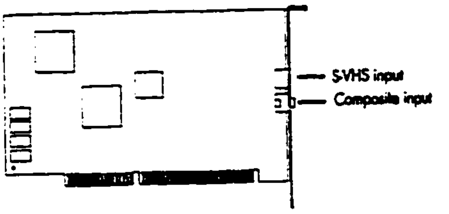
APPENDIX E

SCHEMATIC OF HARDWARE AND SOFTWARE USED FOR VIDEO CAPTURE

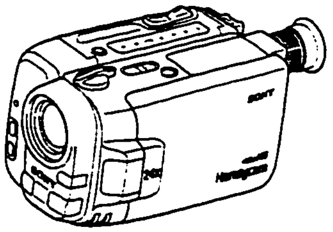
MULTIMEDIA WORKSTATION



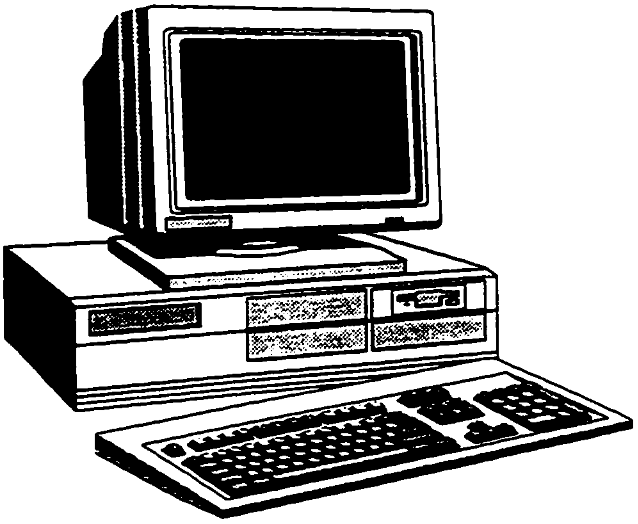
SoundBlaster 16-VIBRA Capture Board



Pro Movie
Studio Frame
Grabber by
Media Vision



SONY - Hi8 Video Camera



15" SVGA Crystal Scan Monitor

Pentium Computer
75 MHz, 8 MB RAM, 540 Megabytes
hard disk space

4x CD-ROM Drive

This is an example of the multimedia equipment used to develop multimedia physics lessons. The authoring software is Asymetrix TOOLBOOK 3.0 (runs under Windows 3.1). The Pro Movie Studio frame grabber utilizes Microsoft's VIDEO for Windows software.