Digital Video, Learning Styles, and Student Understanding of Kinematics Graphs

Teresa Larkin-Hein,
American University, Washington, D.C.

Dean A. Zollman
Kansas State University, Manhattan, Kansas

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Introduction

Student learning is the primary purpose of teaching. However, many traditional teaching methodologies have clearly been shown to put students in the role of passive rather than active learning (Meyers & Jones, 1993). Traditional instructional methods have been shown to be inadequate in terms of promoting deep learning and long-term retention of important physics concepts. Students in traditional classrooms acquire most of their knowledge through lectures and textbook reading. Good teaching involves a great deal more than simply pouring information into the heads of students. Students do not enter the classroom with a tabula rasa. Instead they bring with them their own worldviews which have been developed and formed over their lifetimes. Cobern (1991) describes a worldview as "... how one understands the world" (p. 15). Furthermore, students' worldviews often differ greatly from those of scientists. A troubling fact is, after instruction, students often emerge from our physics classes with serious misconceptions (Arons, 1990; Halloun and Hestenes, 1985; McCloskey, Caramazza, & Green, 1980; McDermott, 1984; McDermott, 1991a).

With the advent of computers, recent decades have seen an explosion in the advances of computer-related technologies in the classroom. In fact, diSessa (1987) has described the computer as a "... once-in-several-centuries innovation" (p. 344). The explosion in the availability of technological tools is literally forcing physics (and other science) educators to change the way they teach. These changes, however, must involve much more than implementing technology for technology's sake. Recent advances in computer technologies and their use in science and engineering education provides an opportunity for educators to take a critical look at how these tools are being integrated into the classroom and laboratory. Research has shown that these technological tools can only be effective in promoting student understanding when

Abstract

This study focused on student ability to analyze and interpret motion graphs following laboratory instruction using interactive digital video as well as traditional instructional techniques. Particular attention was given to students' ability to construct and interpret motion graphs. Two laboratory exercises involving motion concepts (i.e. freefall and projectile motion) were developed for this study. Students were divided into two instructional groups. The students in the treatment group used digital video techniques and students in 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 (Beichner, 1994). Other assessment measures included student responses to various writing 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 (Price, G., Dunn, R., & Dunn, K., 1991) prior to the instructional treatments. Although analysis of covariance statistical procedures revealed no significant difference between instructional treatment and student ability to interpret motion graphs as measured by the Test of Understanding Graphs-Kinematics, the results of this study show that the use of interactive digital video tools can serve to increase student motivation as well as encourage longer time on task. Results of the statistical procedures also showed no significant relationship between students' learning style preferences and their ability to interpret motion graphs. After controlling for potential 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. The resulting mean score on the Test of Understanding Graphs-Kinematics was 10.19 for females and 12.77 for males [$\underline{F}(1,42) = 4.15$, $\underline{p} = 0.048$]. Interestingly, males and females as separate populations had similar mean SAT scores and course grades. Additional studies regarding gender difference are warranted.

used in a pedagogically sound way (Kulik, 1994). Most importantly, close attention must be paid to the use of these tools in ways conducive with cognitive processes of how students learn and retain information in physics. Embedded within this understanding of how students learn physics is the need to know how individual processing styles may affect learning.

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, 1991b; McDermott, Rosenquist & van Zee, 1987; Rosenquist & McDermott, 1987; Thornton & Sokoloff, 1990; Trowbridge & McDermott, 1980; Van Heuvelen, 1991). Students' difficulty in grasping these concepts even after taking the traditional physics courses is well documented.

Trowbridge & McDermott (1981) have shown that students are often unable to discriminate between the concepts of position and velocity even after a considerable amount of formal instruction in kinematics. McDermott, Rosenquist and van Zee (1987) looked at difficulties that students have in making connections between graphs and physics concepts and in making connections between graphs and the real world. These researchers found that when students were asked to produce a motion that is represented pictorially on a graph, they would essentially interpret the graph as a photograph of an event they had observed rather than a depiction of the motion characterized by the particular event.

McDermott, Rosenquist and van Zee asserted that these various difficulties often go unnoticed during traditional instruction. In addition, these researchers have suggested 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 deeper understanding than that which is typically assessed in most traditional physics courses.

Brasell (1990) addressed the issue of experts and novices and the apparent differences in their ability to interpret graphs. Novice graphers appear to 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. Expert graphers, Brasell found, are more able to process the salient features of a graph. In addition, expert graphers are typically able to appreciate the functions of graphs in synthesizing and integrating information and also in summarizing data.

The use of interactive learning tools, such as computer simulations, tutorials, multimedia and computer-based tools, and video can provide students the opportunity to more effectively visualize real-world phenomena and engage in the process of scientific inquiry. In addition, these visualization tools may provide the opportunity for students with diverse learning styles to learn physics more effectively.

Multimedia and Computer-Based Tools - Graphical Construction and Interpretation

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, 1997; 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 video motion analysis software (Beichner, 1996; Brasell & Rowe, 1993).

Brasell (1987) suggested that the simultaneous viewing of a motion event and its graphical representation might prove to be significant in terms of student ability to process information. 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 (Beichner, 1989) 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 a computer animation of videotaped images. Previously taken stroboscopic photographs served as the source of data for students in the traditional labs. The experimental design for Beichner's study involved a two-way analysis of variance on post-test scores of the Test of Understanding Graphs-Kinematics. The covariate used was student scores on a pretest version of the Test of Understanding Graphs-Kinematics. In his study, Beichner concluded that students who had viewed the motion events did not score significantly higher on the Test of Understanding Graphs-Kinematics. However, Beichner did find that males in the study scored significantly higher than females on both the pretest, $F(1, 219) = 4.89$, $p = 0.028$, and the posttest $F(1, 219) = 6.07$, $p = 0.05$.

Brungardt and Zollman (1995) looked at student analysis of videodisc-recorded images with treatments over an extended period of time. Two treatment groups were used: a simultaneous-time group and a delayed-time group. The students in the simultaneous-time group viewed kinematics graphs on a computer screen simultaneously with the videodisc-recorded motion of an 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 a computer screen. Brungardt and Zollman 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 motivation and increased understanding as a consequence.

Interactive Digital Video

Current research suggests active participation by students in the learning process will likely lead to increased learning gains. Kozma and Croninger (1992) suggested that learning with media, particularly interactive digital video, 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.

Chaudhury and Zollman (1994) discussed using digital video techniques to help students understand the concept of frames of reference. Students recorded a video of a ball being dropped in four different reference frames. In terms of experimental design, students were given pre- and post- tests regarding their conceptions of relative motions in various reference frames. Chaudhury and Zollman 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 that focused 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 (i.e. *Video Analyzer* and *Visual Space-Time*). Escalada, Grabhorn and Zollman 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).

A theoretical framework specific to interactive digital video instruction has not been developed (Cronin & Cronin, 1992). The current study was an attempt to provide one example of such a framework by which the assessment of one interactive digital video strategy could be conducted.

Student Learning Styles

Several definitions of learning style exist. Sternberg (1994) defines style as a preferred way of using one's abilities. 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 of 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) likened the uniqueness of individual learning styles to the difference in fingerprints: "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, and similarly, 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 could change over time as a result of maturation. Dunn (1996a) contended that strong preferences can change only over a period of many years and that preferences tend to be overcome only by extraordinary personal motivation.

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. Furthermore, 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). Guild (1994) has suggested that effective educational practices must emanate from an understanding of the ways that individuals learn and their learning styles. In addition, several physics education 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. 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 used interactive digital video techniques.

It is a widely known fact that current technologies, such as interactive digital video techniques are currently growing in use in physics instruction. Although this technology 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 classroom and laboratory settings, lead to increased learner understanding of basic kinematics concepts?

Because of its comprehensive nature and the relative ease of assessing learning styles, the Productivity Environmental Preference Survey was chosen for use in this study. A description of this instrument can be found in the section entitled Performance Measures. 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 using 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.

Purpose of the Study

There were two major goals of this study. The first goal was to study the role that individual learning styles play in relation to students' knowledge of basic kinematics concepts (as evidenced by their ability to interpret motion graphs) presented in the laboratory setting using both traditional and interactive digital video techniques. To address the first goal the following two 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, and

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.

The second goal was to compare the effects of laboratory instruction using 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 using these instruction techniques. To address the second goal, two additional hypotheses were formulated:

1) 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, and

2) 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 used for decision-making purposes.

Additional research questions addressed through qualitative analyses were: Do students with certain learning style preferences as measured by the Productivity Environmental Preference Survey respond better to laboratory instruction via interactive digital video or traditional techniques? How do students' perceptions of their learning styles compare to their scores on the Productivity Environmental Preference Survey? What is the overall relationship between students' learning styles and instructional techniques? 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?

Physics for the Modern World

Participants in this study were students enrolled in an introductory level physics course, Physics for the Modern World, designed for non-science majors during the fall semester of 1996. Students who enroll in this course do so primarily to satisfy the Natural Sciences requirement towards graduation at American University. Many of these students enter the classroom with very limited backgrounds in mathematics and science. Although some students have had a course in high school physics before taking Physics for the Modern World, many have not.

Although traditional in its content, the instructional approach used in Physics for the Modern world was not. 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 class notes so they could focus their attention on listening to the material presented. During other sessions, students spent time working numerical and conceptual problems. Still other class sessions made use of more traditional approaches as they do work well for some individuals. Overall, the instructional approaches employed were designed to address the diversity of student learning styles present in the class.

Laboratory Environment and Experimental Treatments

Research has shown that a single application or treatment using interactive digital video techniques is not enough (Beichner, 1990). With that in mind, two kinematics laboratory experiments were developed for use in this study. One experiment entitled *The Freely Falling Body* involved students' determination of the acceleration due to gravity using a one-dimensional freefall technique. A second experiment entitled *Projectile Motion* involved analysis of the motion of a projectile in two dimensions. These two experiments were designed and used because they allowed a detailed investigation of kinematics concepts using multimedia techniques to probe students' understanding through their ability to interpret motion graphs.

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 (Davis, 1995) as shown in figure 1.

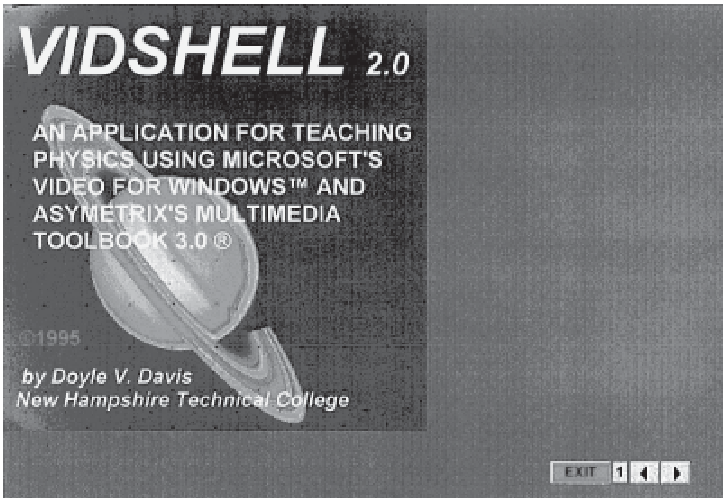

Figure 1. The VIDSHELL Application

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. This data table is displayed in Figure 2. 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. Figures 3 and 4 show that when students took their position-time data using the mouse-pointer and clicked on the falling ball, they were simultaneously able to view horizontal and vertical position-versus-time, velocity-versus-time, and acceleration-versus-time plots of its motion. The students' video clip would appear in the left window and the motion graphs in the right window. 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 feature was not available in any of the commercial software on the market at the time this study was conducted. In addition, 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 or gun 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.

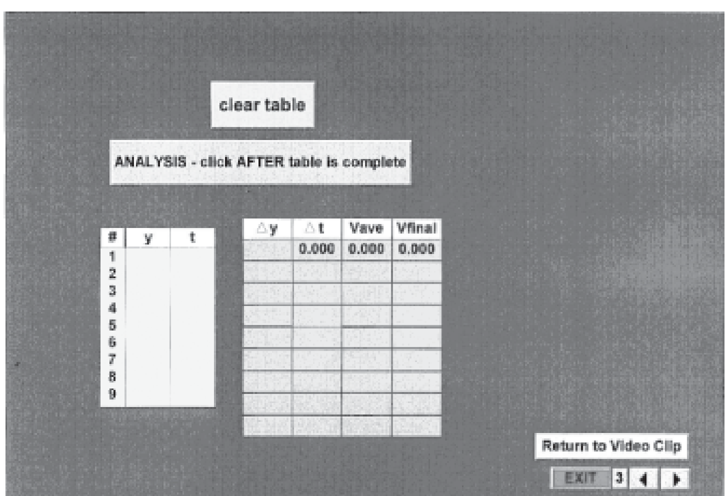

Figure 2. The Data Tables

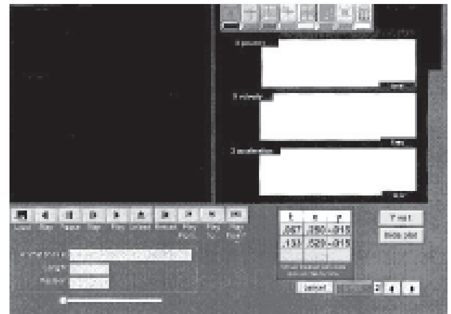

Figure 3. Video Analysis Window Showing Horizontal Components

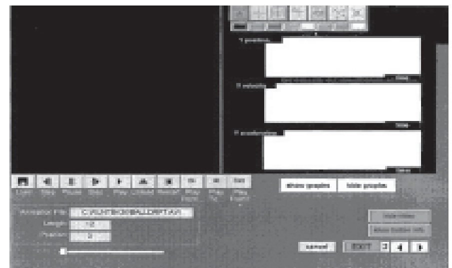

Figure 4. Video Analysis Window Showing Vertical Components

Students using interactive digital video in the *Projectile Motion* experiment used 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.

Performance Measures

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

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. 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.

The final version of the Test of Understanding Graphs-Kinematics was given to 524 high school and college students from around the country (Beichner, 1994). 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 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 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 [$\underline{t}(522) = 1.50$, $\underline{p} < .13$].

Upon further analysis Beichner reported a mean score of 9.5 for males and 7.2 for females who took the test [$\underline{t}(491) = 5.66$, $\underline{p} < .01$]. 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.

The Productivity Environmental Preference Survey (PEPS)

The Productivity Environmental Preference Survey is based on the Dunn and Dunn Learning Style Model. This model is based on five different categories: (1) Environmental, (2) Emotional, (3) Sociological, (4) Physiological, and (5) Psychological. Reviewing 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, chrono-biological 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 Productivity Environmental Preference Survey uses standard scores that 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 find that variable important when they are working and/or learning. Individuals who have scores in the Middle category find that their preferences may depend on many factors. For example, other items such as motivation and interest in the particular topic area being studied may dictate individual preferences falling into the middle range.

Important to note is the fact that the standardized scores (ranging from 20 to 80) that form the basis for an individual's learning style profile can 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.

Writing Activities

Several writing activities were used in the qualitative analysis portion of this study to assess, in part, student understanding of kinematics concepts. These activities also provided a means by which to assess student conceptions of their learning style and the connection(s) between learning style and instructional technique.

As part of their homework assignments, students were required to keep a folder. The folder activities were developed based on research on cognition and learning in physics and learning styles (Hein, 1998). 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 to 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, the folder activity provided a vehicle through which feedback could be given to the students. The importance of prompt and effective feedback to students has been widely documented in the literature (Brown & Knight, 1994; Cross, 1988; Gastel, 1991; Harmelink, 1998; Hein, 1999; Wiggins, 1997).

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 to the 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. Some questions posed pertained directly to the activities that had been performed during the laboratory, while other questions required the students to extend their knowledge beyond that which was performed in the laboratory. Student responses were quantified to permit comparisons to be made between students in each group.

A laboratory questionnaire was also 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 allowed common themes and factors that influenced student attitudes and motivational levels to be uncovered. These responses also served to enforce the observations that were made as students performed each laboratory activity.

Experimental Design

An analysis of covariance, ANCOVA, using the general linear models procedure to account for variations in sample size, was employed. The independent variables were instructional treatment (labeled treatment and control) and gender. 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.

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. Thus, SAT score (as well as course grade) were included 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.

Participants

Sixty-eight students enrolled in four laboratory sections of *Physics for the Modern World* at American University were asked to participate in this study. All students enrolled in these four laboratory sections were enrolled in the same lecture section taught by the author. A graduate teaching assistant taught the laboratory sections. 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).

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 completely blind. Hence, he was not able to participate fully in the laboratory activities. This student did attend all labs and participated to the extent that he could. However, he was 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 this study. However, one of these students 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 analyses.

Results and Discussion

Quantitative Analysis

Analysis of Variance on SAT scores and Course Grades

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.

The results shown in Table 1 reveal a statistically significant difference in SAT scores between instructional groups. These results indicate a mean 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.

Students' course grades, which are assumed to be a measure of student ability to learn a subject, were also analyzed to further explore this potential difference between treatment groups. Total points possible for the course measured course grade. 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 between course grades based on treatment, gender, and their interactions. Although differences were noted between groups based on SAT scores, these differences were not observed based on course grade.

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 x Gender	41907.349	1	41907.349	1.09	.302
Error	1806591.100	47	38438.109		

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 x 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. These results indicate that none of the learning style covariates are significant, and hence, they were dropped from the statistical model. These results further indicate that treatment effects are not significant.

An ANCOVA was then conducted for the Test of Understanding Graphs-Kinematics using SAT score and course grade as covariates. Results from this analysis are given in Table 4. These results indicate a significant difference exists between mean scores on the Test of Understanding Graphs-Kinematics between males and females. After adjusting for SAT score and course grade, the mean score on the Test of Understanding Graphs-Kinematics was 10.19 for females and 12.77 for males.

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.

Relationship Between TUG-K Scores, SAT scores, Course Grade, and Gender

Results of the ANOVA performed on both SAT scores and 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 (maximum possible = 900). The mean SAT score was 1171 for females and 1108 for males, again a difference that 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 are shown in Tables 6 and 7.

A strong correlation exists between SAT scores and mean scores on the Test of Understanding Graphs-Kinematics. This 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 also exists between course grades and mean scores on the Test of Understanding Graphs-Kinematics.

Correlations between mean scores on the Test of Understanding Graphs-Kinematics, SAT scores 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. The low correlation between SAT scores and course grades might be an indication that the males in this study were not working to their potential in the class as predicted by their SAT scores.

These results tend to suggest that if SAT score 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. Based on the similarities between SAT scores and course grades between males and females in this study, 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 of 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.

The following section summarizes the qualitative analysis that was conducted to address the additional research questions posed in this study. Results from observations are presented to help support and make clear this analysis. In addition, results from student writing activities are presented to enhance and support the results presented in the quantitative analysis.

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 x 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		

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 x 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		

Qualitative Analysis

Informal observations were made as students performed the laboratory activities. Each laboratory session was also videotaped in order to support the informal observations. These observations were made, in part, to examine students' attitudes and motivational levels as they performed the laboratory activities. Results from these informal observations revealed that students in the treatment group seemed to focus more on the analysis of the video they had captured and recorded. As a consequence, these students spent more time with their data and in the analysis of the associated graphs.

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 x Gender	1.806	1	1.806	0.10	0.756
Grade	367.957	1	367.957	19.92	0.000
Grade x Treat	22.111	1	22.111	1.20	0.279
Grade x Gender	0.842	1	0.842	0.05	0.832
Grade x Treat x Gender	0.625	1	0.625	0.03	0.855
Error	1015.954	55	18.472		

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

These results were more notable during the second laboratory activity. During the first laboratory activity the students spent considerably more time on the technical aspects of learning to use the computer and video tools. Students in the treatment groups also expressed feelings of self-satisfaction in their ability to work successfully with and use the technology.

A questionnaire was administered immediately after students had completed each activity and before they had left the laboratory. Results of the questionnaire show that students in both groups were enthusiastic about the activities they had 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. 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 that 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 appeared more motivated to conduct repeated analyses of their results than students in the control group. More students in the treatment group focused on comparing their expected results to their actual results, and hence, spent more time discussing them.

Post-lab activities were also administered immediately after students had performed each of the laboratory exercises. The post-lab activities consisted of questions that closely paralleled what students had done in the laboratory exercises. In addition, questions were included that deviated from what students had done in the laboratory and forced students to think very deeply about associated, yet slightly different questions.

One post-lab activity involved asking students to draw position- and acceleration-vs-time graphs for a freely falling object. These students had already drawn the velocity-vs-time graph while they performed the laboratory exercises. Approximately 70% of students in the treatment group were able to correctly draw both graphs as compared to 50% of the students in the control group. Drawing the position-vs-time graph posed the most difficulty for students in the treatment group who successfully drew just one of the two graphs. Furthermore, results from these post-lab activities revealed that many students in the control group understood that the acceleration of a freely falling object was constant. However, these same students had great difficulty in producing the associated position-vs-time graph for the object's motion. Many students could correctly explain that the object was covering greater and greater distances as it fell, but could not translate this into a graphical representation.

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 reflected 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.

Research Implications for Future Studies

This study was conducted primarily within a laboratory setting. Future studies could involve the analysis of interactive video techniques in both the classroom as well as the laboratory setting as they relate to student understanding of kinematics concepts. Future studies involving multimedia tools could also assess learning gains in other subject areas covered in a typical physics course for nonscience majors.

Comparison studies could be done using the techniques developed in this study to address 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 now 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, 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 subjects presented in a typical introductory 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 subjects 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 could be conducted to determine which aspects of learner control are motivating for students. Moreover, assessment tools need to be designed in order to determine whether increased motivation can be translated into increased learning gains. Future studies might also address the issue of student interest and motivation versus student understanding.

Additional studies are also needed which would emphasize 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 science and engineering curriculum. Continued emphasis on the development of a theoretical framework specific to the analysis of the multiple attributes of these multimedia tools is recommended.

Future studies involving multimedia tools and learning styles are also 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 typically performed in a cooperative group environment.

In the current study a gender issue was raised regarding the noted 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 instrument. Additional studies are needed to further explore the reasons for these noted differences.

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

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

Conclusions

Regarding the instructional strategies employed, the 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. Results of the statistical analysis show that a significant difference in mean scores on the Test of Understanding Graphs-Kinematics exists after adjusting for SAT scores and course grades for males and females. This result suggests a possible gender bias inherent in the instrument. Given that, in a previous study, Beichner also found a statistically significant gender difference based on mean scores of the Test of Understanding Graphs-Kinematics between males and females, these results suggest that further studies are needed to address the question of possible bias.

Learning style differences among students were not found to be useful in explaining, statistically, differences in students' understanding of kinematics concepts as evidenced by mean scores on the Test of Understanding Graphs-Kinematics. Although beyond the scope of the present study, additional studies designed to address potential links between learning style, gender, and student ability to interpret motion graphs could provide some additional insights into the gender issues raised by this study.

Results of regression analyses 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.

Students in both treatment groups displayed positive attitudes toward the learning activities they performed. Students in the treatment group showed more motivation to perform repeated analysis than students in the control group. This resulted in students in the treatment group spending more time on task than students in the control group. Additional studies, which focused on the time on task element, would be interesting and potentially useful.

Students who performed the interactive digital video laboratories were better able to produce motion graphs in response to questions that closely paralleled what they had done in the laboratory. However, students in both treatment groups displayed similar difficulties and misconceptions when confronted with questions involving graphical interpretation that differed slightly from the task they had performed in the laboratory.

The use of interactive digital video techniques in the laboratory can serve as an effective tool to permit students to become more active learners. In addition, these video tools can also serve to enhance student motivation and attitudes and encourage longer time on task.

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About the Authors

Dr. Teresa Larkin-Hein is Assistant Professor of Physics Education at American University in Washington, DC. She received her Ph.D. in Curriculum and Instruction with special emphasis in Physics and Science Education from Kansas State University in 1997. Her doctoral work involved the use of an interactive digital video technique as a learning tool for physics students enrolled in a course for non-science majors and an assessment of that technique. Dr. Larkin-Hein's current research involves the assessment of various technological and computer-based tools on student learning in physics. Dr. Larkin-Hein is also studying the role that individual learning styles play in terms of how students learn physics, especially when taught using interactive learning tools such as multimedia techniques. Correspondence regarding this article can be directed to: Teresa Larkin- Hein, Department of Physics, American University, 4400 Massachusetts Avenue NW, Washington, DC 20016-8058. Electronic mail may be sent to: thein@american.edu.

Dr. Dean Zollman, Professor of Physics at Kansas State University, has over 20 years experience working with physics education projects and has, in recent years, concentrated on the use of technology for teaching physics and on providing instructional materials to physics teachers, particularly those teachers whose background does not include a significant amount of physics. Dr. Zollman received his Ph.D. (1970) from the University of Maryland in College Park. He received his BS (1964) and MS (1965) from Indiana University in Bloomington. He is co-author of six video discs for physics teaching, is the director of the software development component of the Physics InfoMall and was a Fulbright Fellow at the University of Munich where he worked with the physics education group on the development of digital video and had the interactive video component of a course for elementary education majors selected by EDUCOM for inclusion in 101 Success Stories of Information Technology in Higher Education (Boettcher, 1993). He was awarded the Robert A. Millikan Medal by the American Association of Physics Teachers in 1995. One of his current research projects involves teaching quantum mechanics through qualitative measures.