Using Interactive Digital Video in an Introductory Course for Non-Science Majors

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The use of digital video has wide-spread applications for classroom and laboratory use. This paper describes two interactive digital video laboratories in kinematics designed for use by students in the introductory course for non-science majors at American University in Washington, DC. In addition, a brief synopsis of a study comparing traditional versus digital video laboratory instruction is presented.

Introduction and Background

Numerous studies have documented students' learning of kinematics concepts in introductory physics classes.[1,2,3,4,5,6,7] Students often have difficulty learning these concepts even after traditional classroom and laboratory instruction. Studies have been conducted which focus on students' understanding of motion concepts using various motion analysis software.[8,9] The use of interactive digital video and other multimedia tools to enhance understanding of these concepts has great potential for physics teaching. Research has recently emerged in physics education which has documented some of the attributes of digital video instruction.[10,11,12,13]

Interactive video and other multimedia tools have been shown to increase student attitude and motivation toward the learning task. One question must be addressed: Do these interactive learning tools serve to enhance understanding of concepts? Additional research that serves to assess learning gains following instruction that utilizes these learning tools is warranted.

Description of the Digital Video Tools and Curriculum Materials

Interactive digital video instruction involves capturing and analyzing of video (from a videodisc, video camera, etc.) using a computer and appropriate software. The video analysis tool developed for use in this study is a Toolbook application called *VIDSHELL*[14]. With this tool, students could analyze video they have captured themselves using a video camera. Two laboratory exercises in kinematics were used. The first was entitled *The Freely Falling Body*, and the second *Projectile Motion.* One group of students performed these activities using traditional techniques (control group) and another group performed these activities using digital video techniques (treatment group).

Students who used traditional techniques used a Behr freefall apparatus for the first laboratory activity. The freefall 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. Position-time data was 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 performed this same 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 in successive frames. As students marked the position of the ball, the position and time data was recorded in a table that appeared on the computer screen. Students used this 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-, velocity-, and acceleration-versus-time plots of its motion. Thus, the interactive digital video application offered students a means to visually see 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 ball. 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 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 group. 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 in *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. Students took these data and drew the same graphs by hand as those students who had taken instruction 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 the captured video.

Assessment Measures

The Test of Understanding Graphs-Kinematics

The Test of Understanding Graphs-Kinematics[15] (TUG-K) was administered to all students after they had performed both laboratory exercises. The Test of Understanding Graphs-Kinematics can be used to help physics teachers and researchers examine what students are learning about the topic of motion via their interpretation of motion graphs. The TUG-K consists of 21 multiple choice items, with three questions for each of seven main objectives. These objectives are:

(1) Give 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.

Writing Activities

Several writing activities were employed to assess student understanding of kinematics concepts. These activities focused on student ability to interpret motion graphs. As part of their 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.

One folder activity on kinematics graphical interpretation was given students prior to receiving the laboratory instructional 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 they liked 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 student ability to understand and interpret basic kinematics graphs.

Summary of Results

Prior to commencement of this study a difference was noted between treatment 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 treatment group prior to commencement of this study.

Results from the Test of Understanding Graphs-Kinematics

After adjusting for SAT scores and course grades, laboratory instructional treatment (interactive digital video versus traditional) was not a significant factor upon students' understanding of kinematics concepts as evidenced by mean scores on the Test of Understanding Graphs-Kinematics [$F(1,47) = 0.00$, $p = .964$]. However, 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 [$F(1,47) = 4.15$, $p = .048$].

Results from the Written Activities

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. A similar number of students in both groups were able to accurately draw velocity- and acceleration versus time graphs given a position-versus-time graph. All students who were not able to draw the graphs displayed similar difficulties. One apparent difficulty was interpreting a curved portion on a position-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-versus-time graph then when determining the instantaneous velocity from the same graph. Students in both groups displayed similar graphing abilities and similar difficulties. These similarities were taken as further evidence that student graphical interpretation ability levels were similar prior to the commencement of the laboratory treatments.

Results of the post-lab activities revealed that students in the treatment group could respond more effectively to questions that pertained specifically to the learning task they had performed than could students performing the more traditional laboratories. Students in both treatment groups displayed similar difficulties when confronted with graphical interpretation post-lab questions that deviated slightly from the tasks they had performed in the laboratory.

Student Attitude and Motivation

Informal observations were made while students were performing the laboratory activities. Students using the 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 computers. However, students in both treatment groups appeared to be motivated and maintained positive attitudes toward learning.

Conclusions

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 teaching applications. A strong component of this study focused on students' ability to interpret motion graphs. 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 and engineering.

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Bibliography

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