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ABSTRACT

The ways in which Digital Video Interactive (DVI), a new video technology, can help students learn concepts of physics were studied in a project that included software design and production as well as formative and summative evaluation. DVI provides real-time motion, with the full-motion image contained to a window on part of the screen so that the remainder of the screen can be used for other purposes. DVI presentations were developed to introduce elementary physics topics. An initial group of 12 graduate Education majors had great difficulty with both the hardware and software. Their suggestions were incorporated into an improved screen design and better user instructions. A second group of four collaborative groups of three Education students was more positive about the experience and provided additional feedback that was used in actual undergraduate classes. Undergraduate reaction to the format and content was much more enthusiastic and is providing additional information for further development. (Contains 37 references.) (SLD)

Title:

Using DVI to Teach Physics: Making the Abstract More Concrete

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INTRODUCTION

This paper reports on a study that used Digital Video Interactive (DVI) to help students learn selected concepts of physics. The purpose of the study was to investigate ways in which new video technologies, such as DVI, can be used to help students learn concepts of physics that traditionally have been difficult to teach. By making those concepts more visual in nature, the topic could become less abstract and more motivating for students to learn.

By teaming two features, the concrete visual images provided by video together with the control over that video, which can be obtained from digital techniques, we hope to be able to make the abstract concepts of modern physics more understandable to students. In this way, it may be possible to attract the interest of students who traditionally have not chosen to pursue the study of physics. This approach may make the physics of the twentieth century more attractive to all students, thus making positive improvements toward equity within science education.

The theoretical underpinnings of a project of this nature must build from research and knowledge about how students learn. Unfortunately, very little research has been completed on student learning of modern physics. Posner, et al. (1982) have looked at the learning of relativity as part of a study on conceptual change. Fischler and Lichtfeldt (1989, 1992) have tested a method of teaching quantum concepts to German school students. Very little research has been reported on the student preconceptions or learning in these specific topic areas, however research has shown that interactive, visual technology has had an impact on the learning process.

Several researchers report positive effects of interactive, visual technology on student performance. Mayton (1991) reports that students who use interactive, visually-based instructional materials outperform others. Abrams and Streit (1986) report greater learning gains. Bunderson, Olson, and Baillio (1981) report faster learning and better retention among students with access to such material. Finally, Cushall (1987) reports more positive attitudes and enthusiasm for the material when students use technology within science classes.

If teachers are to use technology effectively in their teaching, then they need meaningful experiences with using the technology as learners and users (Baird, 1991; Brooks & Kopp, 1989; Smylie, 1989). Future science teachers need experiences using the technology during the course of their training (Sununu, 1986; NSTA, 1990).

Concepts of physics are often presented in an abstract format and are difficult for students to understand. By making the instruction more visual, we hoped to aid the students' understanding of selected concepts in beginning physics. This project used digital video interactive (DVI) to produce and deliver data visualization exercises to students who were studying frames of reference.

The project included software design and production as well as formative and summative evaluation. This paper will describe the development and formative evaluation processes.

BACKGROUND

CD-ROM and videodisc technology can provide visuals for interactive instruction but they offer limited visual capability. Each can provide a moving image, but not in the real-time sense of being able to collect and display experimental data as it is collected. DVI technology has a wide range of capabilities and shows great promise for a variety of educational situations (Ripley, 1990). DVI provides real-time motion: students can collect and visualize data as well as interact with the image on the screen. The full motion image is contained to a window on part of the screen so the remainder of the screen can be used for other purposes, such as graphing data. With the increased emphasis on using computer-based multimedia for instruction, there is a need for evidence of its potential positive effect on learning.

There are many reasons to use computer-based multimedia for instruction; the potential for visual learning and interaction are two of those reasons. Research provides ample evidence for the power of visuals and interactive multimedia to enhance learning (Carlson & Falk, 1990-91; Dwyer, 1978, 1992; Knupfer & Clark, 1992). Computer-based activities provide opportunities for interaction in more than one sense. Interaction can take place between a student and a computer as well as between students who are engaged in cooperative group work.

Because this study contained a large number of females who were minimally computer literate, it was important to investigate the merit of grouping students as well as possible gender and attitude considerations prior to conducting the exercise. A review of the literature indicated that students benefit from working in heterogeneous groups as compared to working alone (Dalton, Hannafin, & Hooper, 1989; Gabbert, Johnson, & Johnson, 1986; Hooper, 1992; Johnson, Skon, & Johnson, 1980; Simsek & Hooper, 1992; Yager, Johnson, Johnson, & Snider, 1986). In addition, heterogeneous grouping of students is preferable to homogeneous grouping (Knupfer, 1993).

There are many positive benefits to cooperative, group work including the ability for students to observe, imitate, and learn from each other (Rysavy & Sales, 1991). Students learning with computer-based multimedia in individualized situations control the pace and sequence of instruction while those learning in small, cooperative groups express more satisfaction (Adams, Carson, & Hamm, 1990; Carlson, 1991). Also, cooperative learning has been rated particularly appealing to low-ability females (Dalton, et al, 1989). The combined strategy of providing computer-based technology and cooperative learning is especially positive for female students; this combination has revealed improved attitudes toward computers and perhaps even more important, it promotes equalized status and respect for all group members instead of competitive and individualistic learning (Johnson, Johnson, Stanne, 1986). Cooperative, computer-based learning reveals no significant differences in the performance of male and female students (Mevarech, Stern, & Levita, 1987; Webb, 1988).

A number of studies have been conducted to compare cooperative and individual learning strategies. According to Johnson and Johnson (1989), a cooperative learning strategy allows students to work together to increase performance and achieve shared goals; an individual learning strategy requires students to work by themselves to accomplish their own goals. Several reviews of research suggest that cooperative learning affects students performance, productivity, transfer of learning, time on tasks, and attitude (Johnson & Johnson, 1989; Rysavy & Sales, 1991; Sharan, 1980; Slavin, 1990).

Investigations about attitudes toward instruction that utilizes computers reveal mixed results. Some studies report no significant effects on learner attitude (Robyler, Castine, & King, 1988; Dalton & Hannafin, 1988), but the majority of studies indicate improved attitudes toward computers (Kulik & Kulik, 1987) or toward the subject matter at hand (Menis, Snyder & Ben-Kohav, 1980; Kulik & Kulik, 1986).

Keller's (1987) ARCS model suggests that motivation in an instructional setting consists of four components: attention, relevance, confidence, and satisfaction. Finally, Debe (1990) suggests that computer-based multimedia best can be utilized in education as a tool to help structure inquiry based on higher-order thinking. Debe draws attention to the similarities between collaborative interaction with peers and the team-based approaches underlying today's science.

This study grouped students into cooperative, heterogenous groups for a DVI exercise meant to stimulate inquiry and promote higher-order thinking to clarify a difficult, abstract physics concept. Students engaged in an activity that would draw their attention to a relevant task, and would hopefully build confidence and satisfaction through a successful experience with physics.

Initially, this study sought ways to improve the teaching of modern physics from two sources. The first source was the literature related to the teaching of modern physics. The second source was the people who work within the field; a series of questions were directed to the physicists, teachers, and students who are subscribers to the PHYS-L computer list.

A review of the literature revealed a dearth of information about ways to improve the traditional physics curriculum. Although some teachers and physicists have questioned which ideas of modern physics should be considered central to a student's development and which ideas are over emphasized in the traditional curriculum, those questions are rather limited in both number and scope. Instead, most of the literature on teaching modern physics concentrates on "tricks of the trade" along with experiments and demonstrations that are most appropriate to students who have a strong interest in physics. There is very little written about shaping the content and and delivery of the physics curriculum to become more appealing to students who lack a natural interest in the topic.

The series of questions to the physicists, teachers, and students who subscribe to the Phys-L list, seemed to offer promise. That group of people has an active interest in physics and views technology as an acceptable means of addressing the problems of teaching. Unfortunately, that attempt at gathering information did not bring any useful results. The few responses that directly concerned the physics curriculum and methodology seemed to suggest a "pet topic" rather than any deep thought. This type of response probably resulted from either a lack of creative thinking beyond the traditional formats for teaching modern physics, or hasty replies to e-mail without taking time to reflect on the topic. Perhaps this approach could be tried again in the future, following some discussion of concrete examples about how DVI could be use in teaching physics.

Some examples of DVI were developed and presented at the a series of physics conferences beginning with Winter Meeting of the Association of American Physics Teachers (AAPT). People were able to interact with the system and discuss various options for improvement. This feedback method yielded helpful suggestions concerning focus topics.

With the lack of response to the electronic questionnaire, research ideas were developed along three parallel tracks with the purpose of investigating appropriate teaching and learning strategies, as follows:

- Development of short lessons using DVI to demonstrate its utility to the physics teaching community.

- Development of concepts and relations among concepts in modern physics for different groups of students.

- Plans for testing some teaching material that used traditional paper as the medium but with an untraditional approach, such as visual quantum mechanics, with the idea of converting it to interactive learning materials using DVI.

Each path would converge on some major themes in the future. This paper describes the project in its current state, with both the successes and problems associated with using the DVI format. It addresses DVI demonstrations, presentation level video, student learning of modern topics in physics, nontraditional approaches of the content of modern physics, DVI as an experiment, hardware and software changes, support for the project, and accomplishments to date.

CONSIDERATIONS ABOUT DVI MATERIALS

The project considered the equipment, its capabilities, the curriculum, and the student audience as follows:

DVI Hardware

The project began by using the Action Media 750 system and exercises were constructed about both visual space-time diagrams and variable quantum effects. The new generation of hardware, the Action Media II system, added certain capabilities, but at the same time sacrificed others. The Action Media II system was used to construct exercises about physically changing reference frames as well as development of mock-ups of progress on the 750 System.

Topics in Modern Physics

The topics selected from the curriculum of the beginning level physics class were visual space-time quantum physics, relative motion, and Quantum Physics.

Real Time Video Capture

The video capturing feature allowed students to conduct a physics experiment, capture a video of the experiment on fixed disk, and then collect and analyze data from the captured video. Students could ask, "What if" questions, change the experiment appropriately, and immediately analyze the data from the new experiment by following its plot on a computer-generated graphic display of the data.

Student Audience

The level of the students was a major consideration in the materials design and the topic selection. The a large class of college students who were studying teacher education, were enrolled in the an introductory physics course that included this curricular material. These students were not science majors, but education majors who needed to study science. The project was visual in nature and promoted visual thinking, so it carried the possibility of using the material with younger students of high school age or upper elementary school age, who were visual thinkers.

DIGITAL VIDEO INTERACTIVE DEMONSTRATIONS

The ability of the DVI system to capture video in real time and manipulate that data was of central interest. This feature, called Real-Time Video (RTV) by Intel, allows individual users to capture video to the hard disk at 30 frames per second. Because the video information is stored on the disk in digital form, one may collect information from the images by performing analysis of them and may alter them in some simple ways.

The first attempt at using RTV resulted in gathering distance-time data about a moving object. Adhering to the theme of investigating topics of contemporary interest, a program was written which analyzes the motion of a spherical pendulum which can undergo chaotic motion. To accomplish this, a video camera was mounted so that it could view the end of the pendulum as it moved. Then the video signal of pendulum's image was captured by the computer. Upon completion of the video capture, an image analysis program found the location of the end of the pendulum and recorded its coordinates for each frame of the video. With this information available, the motion video segment could be played back while simultaneously displaying a graph of its coordinate points.

One limitation of the DVI is it's small window size, yet this feature also has the advantage of offering the opportunity to show four windows on the screen simultaneously. For consistency and clarity of thought, a decision was made to present consistent types of information within the windows. One window always displayed the video of the actual motion while the other windows revealed areas where the students could view plots of distance, velocity, or acceleration versus time, or distance versus velocity. For each graph, the points were plotted as the pendulum moved to the appropriate location on the screen. Thus, the students could watch two dimensional motion which they created and, at the same time, see the graphs of various quantities.

This application of DVI is somewhat similar to the standard approach of using range finders or "smart" pulleys to collect data from one-dimensional motion. For two-dimensional motion, Luchner and Dengler (1989), Keshishoglow and Seligman (1989), and Huggins (1988) have created computer interfaces which can collect information from one bright spot in a video scene. The DVI data collection scheme has both advantages and disadvantages in comparison to these other methods. Unlike the standard range finder, the DVI and other video methods are not limited to one dimensional motion. For the study of chaotic events this additional dimension is very important.

DVI has an advantage over the other video methods because the actual video scene is recorded on the fixed disk. Thus, the students can view their own experiment many times while they look at different ways of analyzing it. In the other methods, the experiment itself is not recorded visually; only numbers from it are recorded. Thus, while the students can complete many different analyses of the data, they cannot look at the experiment exactly as they conducted it.

The most obvious disadvantage of the DVI method is that its sample rate is limited to the frame rate of video (30 frames per second); range finders can sample the data at a much higher rate. Both the range finder and the older video methods can show graphs in real time as the data are collected. With DVI the computer is sufficiently busy collecting and digitizing the entire video image at 30 frames per second that it cannot also display graphs in real time. Thus, the multistep process described above was used. The lack of real-time graphical display does not appear to be critical to this type of measurement because students can view the video of the experiment as often as they wish and compare the video to the graphical data.

A second application of DVI turned the computer into a system for recording time-lapse video. Except for antiquated Super-8 film cameras, the equipment for time-lapse recording is very expensive. Thus, this capability has not been available to students since 8-mm film essentially disappeared from the market. The DVI system is programmed to record a video image in library routines, then DVI can be used to assemble them into a video sequence. Thus the students can record, playback, and analyze events which result in change over a long period of time. For example, students could record and analyze growth patterns within cells or crystals.

RESEARCH QUESTIONS

The goal of this project was to find out if DVI is an effective way to visualize data and if so, whether or not it can help students develop an understanding of the frames of reference physics concept.

Formative Evaluation Questions

1. How difficult was it for the students to understand how to use the software?
2. How difficult was it for students to actually use the software?
3. What did students think of the experience?
4. What suggestions did students have for improving the lesson design?

METHODOLOGY

Subjects

Subjects in this study included two classes of graduate students who served in the formative evaluation by reacting to the exercise as it was developed and providing a basis for revisions to improve the software functionality as well as other elements of the lesson design.

The graduate student classes were of two types. The first class of twelve students who tried the software did not necessarily have familiarity with computers or instructional design. These students were given extremely little introduction about what to expect prior to using the software, but had a follow-through explanation after the exercise. They used the software in discovery based mode as a test to see if the software was sufficiently self-explanatory to allow independent learning. Four collaborative groups of three students used the software and were allowed to discuss the physics problem at hand freely, but they were instructed to keep their reactions about the software confidential until the data were gathered.

All twelve students had difficulty with both using the computer equipment and understanding the physics concept of frames of reference. The reaction to the experience was generally negative and reflected frustration despite the collaborative structure of the exercise. The students did not believe that this exercise could stand independently, but suggested that the instruction include an introduction to both the equipment and the frames of reference topic.

Based upon feedback from the first group of graduate students, modifications were made to the software and to the method of introducing the material to the students. The second group included students who had experience with design for interactive multimedia-based instruction. This class was given slightly more introductory information about both the physics frame of reference concept and how to use the equipment.

Modifications to the software functionality included an improved screen design with navigational buttons that closely resembled a video cassette recorder (VCR) to be used during the data collection and analysis. Functions allowing the collection and analysis of data were clearly labeled and students were able to try the different functions at will.

Modifications to the frames of reference topic did not delve into depth on the concept, but instead provided brief, verbal information about the goal. Students received this information in the context of seeing how to use the camera to record a dropping ball from a stationary cart and a moving moving cart. Like the first group, the second class of twelve graduate students tried the exercise within collaborative learning groups of three and responded to the experience both in writing and verbally.
This group of students reacted more favorably, but still had problems with understanding the context of the physics lesson.

The frame of reference lesson was intended to use with undergraduate students who were taking an introductory course called *Concepts of Physics* in partial preparation for careers as elementary school teachers. Based upon the feedback from the formative evaluation, the lesson for the undergraduate students included the frame of reference concept within the first few lectures of the semester. This preliminary information released the students from the content struggle and helped prepare them to take advantage of extending their learning to a different level of experience.

The *Concepts of Physics* class utilized lectures, demonstrations, and laboratory exercises. The frame of reference concept was taught in lecture during the first couple of weeks of the semester as part of the regular curriculum and thus the concept was tested in the first exam of the course. Nothing further was mentioned about frame of reference during the course. During the last two weeks of the semester, the students used the DVI exercise. The exercise consisted of a pretest, the DVI exercise, and a posttest. Finally, four frame of reference questions were included on the final exam.

Armed with the prerequisite physics content, the students were then grouped into collaborative groups of three and were provided with more information about working the equipment than their graduate student colleagues had been given. The goal was to provide enough information to the students so that they would be able to use the equipment with comfort. The undergraduate students were much more positive about the experience and nearly 100 percent of them claimed that the DVI visualization experience helped them to understand the frame of reference concept. An analysis of their performance scores will be provided in a forthcoming report.

Although the exercise provided a stimulus to engage the attention of the first two groups of graduate students, only the undergraduate group had the benefit of perceiving the exercise as relevant to their course, confidence in knowing their goal, and satisfaction of realizing how the DVI exercise fit within the whole. Only the undergraduate students realized the four components of Keller's ARCs model (1987) and reacted favorably to the exercise.

RECOMMENDATIONS

This formative evaluation clearly points out the need to prepare the learners with adequate information about the topic of study as well as the equipment. Although developers of electronic educational material might view the use of such material as easy, others who are unfamiliar with the material are likely to need assistance in gaining perspective on the material prior to using it.

This DVI material needs to proceed to summative evaluation to measure both its perceived value and it effectiveness for helping undergraduate students learn about the frame of reference concept. In the future, it might be possible to try test the ability of the DVI exercise to extend the physics lesson frame of reference to younger learners, such a those in the upper elementary school. The frame of reference concept has traditionally been taught at the undergraduate college level, but the rich visualization made possible with DVI might enhance the experience to the point where it becomes valuable for younger learners, thus changing the science curriculum.

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