TECHNOLOGY AS A TEACHING AND LEARNING TOOL: ASSESSING STUDENT UNDERSTANDING IN THE INTRODUCTORY PHYSICS LAB

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Abstract

Technology, particularly computer-based applications are currently being incorporated within many domains of science, mathematics, engineering, and technology (SMET) education. The primary goal of this incorporation is the improvement of student learning. In this paper we focus on strategies designed to improve student learning following instruction that utilizes technology-based learning tools in the introductory physics laboratory. To address this issue, we describe an interactive laboratory experiment designed to teach the concept of momentum and impulse to introductory physics students. The laboratory activity makes use of a collision apparatus and computer interface to allow students to determine relevant data. An interactive software tool allows students to perform a series of analyses of various elastic and inelastic collisions. We will link the discussion regarding the use of these technology-based learning tools in the physics laboratory to specific strategies that can be used to assess student learning. Relationships between student understanding and individual learning styles will also be shared. This discussion will have broad applications for the effective utilization of technology within the domains of SMET education.

I. Introduction

A growing number of technology-based educational learning tools currently exist within the domains of science, mathematics, engineering, and technology (SMET) education. In addition, the use of educational technologies is growing both in and out of the classroom and laboratory. Certainly technology has the potential to serve as a powerful tool to improve the educational process for students as well as teachers [1]. However, educational technology is only as good as the content it supports [2]. Therefore, it is important to address such issues as learning goals and curriculum objectives before one implements any form of technology as a learning tool.

Many traditional teaching methodologies have clearly been shown to put students in the role of passive rather than active learning [3]. Traditional instructional methods have also been shown to be inadequate in terms of promoting deep learning and long-term retention of important physics concepts. More often than not physics is taught in a typical lecture-style format in which the instructor provides information to the students by talking to them. This style of instruction focuses primarily on the instructor, the only active participant in the class. Although optimum for some, this mode of instruction is deficient in many ways for most students. One outgrowth of much research in physics learning is the basic idea that in order for meaningful learning to occur, the learner must be given the opportunity to interact actively with the material to be learned [4 – 6].

The explosion in the availability of technological tools is literally forcing those who teach physics as well as other SMET educators to change the way they instruct students. These changes, however, must involve much more than simply implementing technology for technology's sake. The recent advances in computer-based technologies and their use in SMET 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 if used in a pedagogically sound way [7]. Furthermore, once we have established what it is we want our students to understand, we must determine a way to help him/her do just that! The use of technology may serve as one tool to help students gain the knowledge that has been ascertained as important.

It is essential to note at this point that the integration of computer-based technologies into the classroom and laboratory is not enough. Strategies must be employed which are designed to assess student understanding following the use of any new type of learning tool, computer-based or otherwise. Furthermore, effective strategies must be developed and implemented to assess overall student learning gains. Teachers need to make wise decisions about how and why computer-based technology should be used in the classroom [8].

An important question that must be addressed is whether computer-based learning tools are effective for all students, or only those with particular learning style characteristics. A growing body of research on adult learners suggests that increased learning gains can be achieved when instruction is designed with students' learning styles in mind [9 - 11]. Thus, it is desirable to study the potential relationships between the learning strategy employed and individual learning styles.

One purpose of this paper is to describe a computer-based learning strategy employed in the introductory physics laboratory at American University. A description of the learning style assessment tool employed in this study will be given. In addition, strategies used to assess student understanding will be shared. Finally, connections between student understanding and individual learning styles will be provided along with directions for our continued research.

II. The Introductory Physics Course at American University

The introductory course for non-science majors at American University in Washington, D.C. is a one-semester, algebra-based course and is entitled *Physics for the Modern World*. Topics covered in the course typically include Kinematics, Newton's Laws, Conservation of Momentum and Energy, Rotational Motion, Fluid Mechanics, Waves, and Sound. Although traditional in its content, the course is not taught in a "traditional lecture format." Numerous teaching strategies have been developed which correspond to the accommodation of students' diverse learning styles [12]. In addition, the course includes both strong conceptual and problem solving components.

Physics for the Modern World is a 3-credit course and consists of both a lecture and a laboratory component. Students meet twice a week for class sessions that are 75 minutes long. On alternate weeks students meet for a two-hour laboratory. Approximately 120 students, with 60 students in each of two sections, enroll in the course each semester.

Many students who enroll in *Physics for the Modern World* are liberal arts majors. A typical class consists of a mixture of students from the College of Arts and Sciences, the School of Public Affairs, the School of International Service, and the Kogod College of Business Administration. Students enroll in *Physics for the Modern World* to satisfy a portion of the Natural Science requirement for graduation at American University. Students may choose to satisfy this requirement with a general Physics, Chemistry, Biology, or Psychology course.

Due to the wide range of majors in the course, one could assume that the diversity of students enrolled in *Physics for the Modern World* closely parallels the diversity of students enrolled at American University. The 1995 - 96 American University catalog describes its student population as being "... cosmopolitan and multicultural ..." [13]. The spring 1999 classes of *Physics for the Modern World* include students from 24 states and 25 countries. Nearly 40% of this class is made up of international students.

III. Description of the Laboratory Activity

The laboratory activity developed for use in this study is entitled *Conservation of Momentum* and was designed to help students learn the concepts of momentum and impulse. The apparatus used involves the use of a dynamics cart accessory track set available from Pasco Scientific [14]. This apparatus includes a 1-m track with a set of two gliders used to create elastic and inelastic collisions. Photocells interfaced to a computer are used to help determine the velocities of each glider before and after the collisions. The software package used is called *Logger Pro* [15].

In the *Conservation of Momentum* laboratory activity, students make use of the track and gliders to establish elastic and inelastic collisions. Students can make use of the photocells and software to help them determine the velocities of the gliders before and after each collision. Knowing the masses of the gliders and their corresponding velocities, students are able to determine the total momentum of their system before and after each collision. From this determination, students are able to verify that momentum has been conserved for each collision.

Of particular interest is student ability to understand the entire collision process. This process involves a fundamental understanding of the force and time involved for each collision. The product of the force and collision time yields a quantity called impulse. Impulse, by definition, is equal to change in momentum. In addition to understanding the concept of momentum conservation, students are also challenged to demonstrate their understanding of impulse in a collision. The concept of impulse is one that tends to be problematic for many students.

IV. Learning Style Described

Several definitions of learning style exist. Sternburg [16] defines style as a preferred way of using one's abilities. Dunn [17] has 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.

The Dunn and Dunn Learning Style Model was chosen for this project because of its comprehensive nature, and, because of the numerous research studies that have been conducted with the model documenting its reliability and validity [18]. This model is based on five different categories: (1) Environmental, (2) Emotional, (3) Sociological, (4) Physiological, and (5) Psychological. The learning style assessment instrument chosen for this study is the Productivity Environmental Preference Survey (PEPS) by Dunn, Dunn, and Price [19]. This assessment instrument was chosen because of its comprehensive nature, and, because of the relative ease of assessing students' learning styles and interpreting the results. The PEPS instrument is described in more detail in the following section.

The Productivity Environmental Preference Survey (PEPS)

The PEPS instrument consists of 100 questions on a Likert scale. The scoring system for the PEPS instrument uses standard scores that range from 20 to 80. The scale can be further broken down into three categories that can be referred to as Low, Middle, and High. The Low category represents standard scores in the 20 - 40 range; the Middle category scores in the 41 - 59 range; and the High category scores in the 60 - 80 range. Individuals who have scores lower than or equal to 40 or higher than or equal to 60 for a particular element find that variable important when they are working. Individuals who have scores in the Middle category find that their preferences may depend on many factors (e.g. motivation and interest in the topic being studied). The numerical scale system allows for appropriate statistical analyses to be performed as necessary.

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

The PEPS was administered to all introductory physics students at the beginning of the spring 1999 semester. The completed assessments were sent to Price Systems, Inc. in Lawrence, Kansas for scoring. Once the students' scores are received, individual homework prescriptions were prepared for each student using a software package designed specifically for that purpose.

Once the PEPS has been administered, students should receive this feedback profile as quickly as possible. The standardized scores (ranging from 20 to 80) that form the basis for an individual's learning style profile may be easily misinterpreted. Students immersed in an academic

environment may tend to interpret a higher score as being better than a lower score. Students must immediately be made aware that no high or low exists on this scale in terms of superiority of scores. Furthermore, no scores are ever bad scores - all are simply unique. The message to the student must be clear: learning styles are unique to the individual and are not to be labeled as being good or bad. No scientific evidence shows that one type of learning style is academically superior over others.

V. Assessment of Student Learning

The assessment strategies designed for use in this project were both formative and summative in nature. Formative data was collected using classroom assessment techniques such as those developed by Angelo and Cross [20]. Cross [21] indicated that the use of classroom assessment techniques provides for powerful formative assessment strategies. One example is the Minute Paper that is typically given during the last few minutes of a class session. On the Minute Paper students are asked to state which concepts they found most helpful and to state what questions still remain at the close of the class session. When students are put on notice that they will be asked to respond to such assessments it makes them keenly aware that they will be expected to be able to synthesize and articulate their learning. In this way students (even in large classes) are expected to be active learners by raising questions and thinking about the implications of the material that has been presented and shared during class.

In addition to classroom assessment techniques such as those mentioned above, additional data was collected from the individual learning style assessments. Demographic as well as other background information about the students was collected using a questionnaire given students on the first day of class.

More summative forms of assessments used include student writing activities as well as more standard forms of assessment (i.e. classroom examinations and quizzes). One specific writing activity allowed for a pre-assessment of students' understanding of the collision process before they had received formal classroom and laboratory instruction on the concept of momentum. This writing activity is described in the section that follows.

The Writing Strategy: Assessment of Student Preconceptions

The writing activity used to assess student understanding is called a *folder activity* and was developed by the lead author for use with introductory physics students [22]. As part of their homework assignments, students are required to keep a two-pocket paper folder. Students make one entry in their folders approximately every other week. Students receive specific written feedback in their folders designed to help them uncover potential problems in their understanding of a particular concept or idea. Students are encouraged to reflect on feedback they receive and then work to confront any potential difficulties they are having with a particular concept. When students take time to reflect on their writing and on the instructor-given feedback, the folder becomes a highly effective tool in helping them uncover and then wrestle with their misconceptions while the learning is taking place [23]. The writing activities provide a window into understanding how well students are integrating the new knowledge into their existing knowledge schemas, thus providing a valuable tool in encouraging deeper understanding

and retention. The folder activities are not graded based on students' correct use of physics but are a required component of the course. Essentially the folder activities provide students an opportunity to make mistakes, confront and then correct them, before they are asked to perform on a quiz or exam.

For the current project, students were given a writing activity associated with the concepts of force and momentum before they had performed the actual laboratory activity. In this manner, misconceptions that were present before the laboratory activity was performed could be uncovered. This writing activity served as a pre-assessment of students' understanding of the collision process before they had received formal instruction on this topic.

The specific writing assignment given students was as follows:

If a Mack truck and a Honda Civic have a head-on collision, upon which vehicle is the impact force greater? Which vehicle experiences the greater acceleration? <u>Explain your responses</u>. Next, do your best to thoroughly describe what happens to the momentum of each vehicle before, during, and after the collision.

The correct response to this assignment is that the force on each vehicle should be the same via Newton's 3rd Law. Further, the Honda Civic should have the greater acceleration due it's smaller mass (via Newton's 2nd Law). In addition, the momentum of each vehicle changes by the same amount during the collision. Responses received from students clearly indicated that some common misconceptions existed in their understanding of the collision process. The following are some typical student responses to this assignment:

<u>Student 1</u>:

"The force of impact will be greater for the Mack truck in a head-on collision because its mass is greater. Since the mass is greater, the force will be equally greater because force = mass × acceleration. The acceleration will be greater as well because of the greater mass. The momentum before the collision is greater for the truck but when they collide the momentum of both is zero."

<u>Student 2</u>:

"If a Mack truck and a Honda Civic had a head-on collision the impact force is greater on the Honda because its mass is less. I believe that the Honda would experience the greater acceleration considering that its initial speed and direction (velocity) would be affected more by the collision. I think the momentum of the truck is greater than the momentum of the Civic because, even if the vehicles travel at the same speed, the truck has more mass (therefore more force, inertia, and momentum) than the Honda. Then, I think the momentum of the Honda is instantaneously stopped by the force of the truck at the time of impact. Following impact, the truck and car would have the same momentum, because the greater force of the truck would push the car backwards and share its momentum with the Honda."

Student 3:

"If a Mack truck and a Honda Civic have a head-on collision, I believe the Honda Civic will have a greater force of impact upon it. If both the Mack truck and the Honda Civic are traveling at the same speed the Mack truck will place more impact force upon the Honda Civic because the Mack truck has the greater mass. I think force is determined by a combination of speed and mass. The momentum of both the Mack truck and the Honda Civic will be in opposite directions facing each other before the collision. As soon as impact is made, the momentum for both continues in opposite directions as each absorbs the impact force of the other. Since the impact force of the Mack truck is greater than the impact force of the Honda Civic the momentum of the Mack truck will continue in the same direction during the collision. The momentum of the Honda Civic will be in the same direction as the Mack truck throughout the collision and after the collision. The speed of each vehicle also plays a part in determining the momentum once impact is made. In this example I believe both vehicles are traveling at the same speed and since the mass is so much greater for the Mack truck the speed plays less of a role."

Clearly there are several misconceptions that become apparent through these students' written responses. The most common misconception involves a problem with understanding that the time represented in the impulse relationship represents the collision time. Another common misconception is the idea that the mass of the colliding object dictates the size of the force. Since this writing assignment was given before students had received any formal classroom or laboratory instruction on the topics of force and momentum, it is not surprising that many students displayed difficulty understanding these concepts.

After students had submitted their writing assignment, written feedback was provided to them from the instructor. The intent of the feedback is to assist students in correcting their misconceptions as they continue to learn the material through classroom and laboratory activities.

Given that this study is currently in progress, final results as to students' performance following the laboratory experiment they performed are not available. Further assessment of the laboratory activity on students' understanding will include their responses to a written post-lab activity that will be given them immediately after they perform the collision experiment. In addition, other more summative forms of assessment such as classroom quizzes and examinations will also serve to assess students' understanding of the collision process.

One important aspect of writing activities such as the *folder activity* and the Minute Paper is that students are permitted to be as creative as they would like to be when they submit these assignments. Students are encouraged to write their responses in a fashion that allows them to make use of their individual learning styles. For example, some students like to enhance their writing through the use of manipulatives and artistic drawings. Other students might choose to write their responses in the form or a story or short play. The students know that they have complete control of this activity and are free to put their individual learning styles to good use!

VI. Learning Styles and the Assessment of Student Learning

The assessment of individual learning styles does not link itself directly to effective instructional design. The best teaching strategies involve the incorporation of a variety of instructional techniques. The individual learning style assessments ARE important in that they will allow for possible connections to be made between specific learning style strengths and student learning gains that result from instruction that includes the use of computer-based technologies.

Once the current study is completed, learning style data will be linked to student performance on the various strategies used to assess student understanding. For example, the laboratory activity involves a hands-on approach. We would like to be able to determine whether students who have a tactile learning style preference perform better when given the opportunity to perform the laboratory activity as opposed to traditional teaching strategies. Thus, we plan to use the data collected to help us determine the role(s) that learning style may play in terms of student understanding of the collision process after exposure to the interactive laboratory experiment on collisions. In addition, we plan to further analyze the relationship between learning style and strategies of instruction that may or may not result in differences in student performance on the variety of assessment measures used. These results will be shared in a future publication.

VII. Summary – Directions for Further Research

At this writing data collection is ongoing. Thus, a more formal presentation of actual results will be presented during the ASEE conference. Results from the formative and summative assessments will also be shared at that time.

Future plans include the addition of other forms of data collection techniques to assess the utility of these computer-based learning tools. For example, we plan to collect empirical data by observing students at work with the new technologies. In addition, we plan to collect empirical data through the use of structured, open-ended interviews as well as individual demonstration interviews. As appropriate, these interviews will involve having students work with a particular computer simulation or tutorial related to the concepts of momentum and impulse and will follow a standard “think aloud” protocol. Data collected from these observations and interviews will be analyzed using protocol analysis techniques [24].

The assessment of student understanding as well as learning gains is a critical component of any instructional strategy. When new computer-based technologies are utilized, these assessments become a vital and necessary component. Finally, we intend to continue our studies into the role(s) that learning styles may play in terms of enhancing student understanding following instruction that makes use of computer-based learning tools.

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