Development of A Web Based Multimedia Physics Lesson

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I. Introduction

Physics can be one of the most difficult subjects for students to comprehend. Throughout the country, introductory physics is one of the most dreaded courses on college campuses. Why physics is such a challenging subject for students is a difficult question to answer, but recent research on cognition and learning[1] has suggested more effective techniques for teaching physics[2]. Some of the most exciting improvements have come through the advancement of technology and the use of computers.

Computers can allow the scope of the traditional classroom to be expanded significantly. With just a few simple clicks of the mouse, a student could find a video of a space shuttle launch on the web, take position and time data from the video, enter the data into a spreadsheet program, and analyze the data. By allowing students to observe experiments that interest them, as opposed to limiting them to experiments that can be performed in the lab, computers can make physics much more approachable. Students can go places they could never go, observe experiments they could never perform, and analyze data by hitting a few simple buttons. These capabilities make computers a powerful tool in the physics classroom.

While computers have great potential, they also have many draw backs. First of all, most software is platform dependent. In other words a great piece of software may only work on Macintosh computers, or a certain type of file may be more compatible on one type of computer as opposed to another. Additionally, software must be installed on to each computer where it will be used or be restricted to a local area network. These limitations can mean that students are restricted to using certain programs on certain computers. In the ideal learning environment, a student would be able to access all of the resources needed for a lesson from any computer available.

This paper will focus on the development of a web based multimedia physics lesson. This approach allows for the use of a computer's powerful capabilities, while eliminating several of their down falls. By posting a lesson on the web, it can be accessed by any computer on the Internet with a web browser. Furthermore, with the use of the Java programming language, programs can be posted on the web that will theoretically work on any computer with a Java enabled browser. Ultimately, this means that a web based lesson could be accessed from virtually any computer in the world with an Internet connection, regardless of whether the computer is an IBM, Macintosh, or some other platform.

In order to fully understand the potential of web based physics lessons, this paper will examine several of the issues surrounding computer lessons. The history of computer lessons will be explored by discussing the software that is currently on the market, and then the advantage of using the web and Java programming will be further explored. Finally, the experience of making an actual web based multimedia physics lesson will be used to display the more technical issues, as well as providing some insight into what approaches seem to work best in multimedia lessons. Overall, this paper will identify several potential methods for using technology which could open the door to greater student understanding of complex subject material.

II. A Brief History of Computer Based Physics Software

Computers and other forms of technology have been used to supplement the physics classroom for some time. The most well know examples include platform-specific computer tutorials, computer simulations, drill and practice programs, and video-based lessons delivered on laserdisc. The more advanced uses of technology combine video and simulation software with machine feedback to provide a more interactive lesson.

Laserdiscs were one of the first multimedia supplements to the physics classroom available. Basically, these laserdiscs contain videos of numerous physics demonstrations, and they can be played on a regular laserdisc player. Frames on a laserdisc can be randomly accessed and stepped through from frame to frame, which makes taking and analyzing data fairly easy. These discs are relatively simple to use, and by allowing students to observe numerous experiments, instead of just a few performed in the lab, the disc can greatly expand the scope of a physics class. Unfortunately, since laserdiscs only allow student to view experiments that have already been performed, they limit the range of interactivity possible.

A more interactive approach to computer based physics lessons came in the form of computer simulations of various experiments. For example, a software program, such as Interactive Physics[4], might present a student with a certain mass, and allow the student to apply a simulated force to that mass. Then the student can run the simulation and see how the mass will react under that force. Computer simulations can allow students to run trials of an experiment that are not possible in a traditional lab, as well as enabling the student to run several more trials than would be possible otherwise. Curriculum materials have been developed for the Interactive Physics simulation package.[5] While computer simulations are more interactive, they generally do not take full advantage of a computer's multimedia capabilities, and they have been platform specific, which limits the number of computers they can be used on.

The next logical approach for computer based lessons was to integrate the use of multimedia, like video in the laserdiscs, with the interactive nature of computer simulation programs.[6] These types of lessons begin to use the full power of computers. Multimedia applications, like videos, can be used to illustrate various physics problems with real life examples, and then an interactive simulation program can help further a student's understanding of the situation. In a sense, it is the best of both worlds, unfortunately getting all of the various multimedia and simulation applications to work together, on one computer, can be a challenge.

To further bring interactive programs and multimedia applications together, some commercial programs like Toolbook and Authorware have tried to combine all the elements of a lesson into one program. This is probably the best approach readily available today. Since everything needed for the lesson is in one program, getting it to work on a computer is much simpler. The only major disadvantages of this method is that the programs typically only work on one platform, since they are written in programming languages that are proprietary rather than standards-based. Additionally, the programs still must be installed on each computer or work in a LAN environment, so that students are still limited to which computers they can use to access the lesson.

Overall computer based lessons have evolved to make full use of a computers capabilities, while providing an interactive learning experience. This holds great potential for increasing the number of educational opportunities in the tradition physics classroom. Right now, the main obstacle for computer lessons is providing universal access. Lessons need to become versatile enough to be accessed from virtually any computer, while still effectively using the multimedia abilities of today's computers.

III. Web Based Lessons

Making computer lessons universally accessible involves overcoming two main obstacles. First, a lesson must be accessible from any computer. Ideally this would mean any computer in the world. Second, a lesson should be compatible with any computer platform. Both of the issues can be handled by taking advantage of the World Wide Web and the capabilities of today's browsers.

Instead of writing a lesson in the form of a program that must be installed on a computer, a lesson could be written in HTML and a scripting language like JavaScript, and then posted on the web. With a web based lesson, anybody in the world with a web browser can access the lesson. This means that students could access a lesson from the physics lab, residence hall lab, their dorm room, or even from home during a vacation. Since today's web browsers allow the use of a variety of multimedia files, a web based lesson can contain just as much multimedia as any other computer based lesson. With the addition of Java and Javascript, lessons on the web can also be very interactive.

While a lesson on the web can potentially be accessed from anywhere in the world, there can still be problems with it working on different platforms. The use of Java programming can help solve this problem. With other programming languages, a program is written and then compiled to work on a specific platform. Java, on the other hand, is written and then compiled in two stages. First it is precompiled in a from that can be recognized by any Java enabled browser, and then the browser performs the final compilation, so that the program will work on the specific platform of the individual computer. This seems to be the last major step in writing a computer lesson, which can theoretically work on any computer available.

The universal access of web based lessons has incredible potential. Not only is the scope of the physics classroom expanded through the use of a computer's multimedia capabilities, but the classroom itself is expanded to dorm rooms, homes, or anywhere that there is a computer connected to the Internet. Now students can do their homework whenever they want, or review a physics lesson from any computer they have access to. Web based lessons can theoretically overcome many of the disadvantages that earlier computer lessons faced.

Naturally, in real life web based lessons do not yet live up to their potential. To begin with, not all computer platforms support Java at the same level. If a program is written in the latest version of Java, it might only work on platforms that support that level of Java. Also, different browsers tend to behave differently. This means that a web lesson which looks great on Netscape, may be awkward and confusing on Internet Explorer. Again, the problem of making a truly interactive multimedia lesson, that is universally accessible, becomes challenging. However, most of these problems are minor and will soon be eliminated as the computer industry progresses at a rapid pace. Web based lessons are definitely worth developing, and soon they should be able to reach their full potential.

IV. Lesson Design

Before jumping into the technicalities of designing a web based physics lesson, it is important to discuss the most effective methods for designing an interactive lesson. Technology can greatly enhance a well designed lesson, but the greatest computer in the world can't save a poorly designed lesson. Obviously the theory behind lesson design can be controversial, but there do appear to be some definite winning strategies. The best lessons seem to actively engage the student in an ongoing learning process, rather than force the student to passively accept information.[2]

Most lessons can be clearly labeled as active or passive learning. In active learning the student is a constant part of the lesson. This involves instant feedback to the student's progress in the lesson, which is used to adjust the lesson to each individual student's experience. Passive learning on the other hand is more of a one-way learning experience. With a passive lesson, a student will generally only receive information and have little control over the progress or content of the learning experience.

It seems clear that passive lessons are a thing of the past. In order for a lesson to take full advantage of a computer's interactive capabilities, it should be designed for active learning[7]. Ideally, the student should be asked for input at every step of the lesson, and the input received should directly affect the progress and direction of the lesson. Multiple choice, short answer, and essay questions are just a few of the possible ways to acquire student input with which to guide a lesson.

Active learning allows the lesson to be individualized for each student. A student can spend more time in areas that he or she finds difficult, and quickly move past areas that are easily understood. This strategy not only makes the lesson more effective, but it also makes the experience more enjoyable and interesting to the student.

While it seems obvious that lessons should be guided by a student's input, the exact way to guide a lesson based on that input is less clear. The learning cycle has gained a lot of support[3], and it was used as a basis for the web lesson that will be discussed in this paper. Basically, the learning cycle uses a circular structure in the lesson design. The student starts by developing some basic concepts over the material in an exploration stage, then the student practices applying those concepts in an application stage, and finally the student's progress is assessed in an evaluation stage. The most effective learning cycle lessons allow a student to easily move between stages as needed. For example, if a student is having difficulty in the application stage, he or she can go back to the exploration stage to better understand the concepts being used in the application.

When implemented well, the learning cycle allows students to gain a deep understanding of the material. Students learn to associate different aspects of a lesson with their relationships to each other. This ultimately leads to a broad understanding of the overall system being studied, as opposed to a memorization of specific instances. The learning cycle has great theoretical potential, however it tends to lead to complicated computer based lesson designs. Since learning cycle lessons contain numerous links inside the lesson, they tend to deviate from a simple linear design, and are thus challenging to implement. With careful attention to detail though, these difficulties can be overcome and a great lesson can result.

In order to illustrate and study the design of an interactive multimedia computer lesson, a web based lesson over force was created using HTML, JavaScript, and various multimedia files. The lesson starts with an exploration in which several real world examples of force are presented via Quicktime videos, and then the students were asked to think about the properties of force and how they might be described. Newton's and Aristotle's laws are discussed, and an application was created so that the students could develop a mathematical description of force based on concepts from the exploration. Finally, the student's progress was measured with a short quiz in the evaluation section of the lesson. This lesson was able to provide insight into what benefits a web-based lesson using the learning cycle can have, and it also identified problem areas in the design and implementation of such a lesson.

A formative assessment was made by observing students while they took the web-based lesson over force. This assessment included students with and without previous exposure to mechanics in introductory physics, and some positive and negative aspects of the lesson became noticeable. From a design standpoint, the lesson appeared to be on fairly neutral ground.

The first thing that became noticeable in the assessment was that a learning cycle lesson can be just as confusing to take as it is to design. With so many links back and forth between different areas of the lesson, some students tended to get lost and off track. This was not an overwhelming problem, but it did illustrate the advantage of simplicity. Lessons should have a clear and simple objective; there is little to be gained by stuffing as much information as possible into one lesson.

Additionally, it became essential for students to have a way to jump in-between different areas of the lesson at their will. In the force lesson, this was done by using frames to create a navigation bar which was always available on the side of the screen. When students got off track, they were able to use the navigation bar to find their way back. A lesson with a clear objective and easily accessible navigational tools is essential to the success of the learning cycle.

The formative assessment did show that the force lesson was more appealing to students than a traditional lesson. The students indicated that they enjoyed being able to work at their own pace and spend time on the areas of the lesson that they wanted to. Most of the students took the opportunity to look back at certain areas of the lesson, and the ability to repeat a demonstration over and over again appeared very beneficial to the students.

Overall, the formative assessment displayed the potential benefit of the learning cycle's ability to reinforce concepts, while stressing that a good lesson must be clear and easily navigable. It was also clear that active learning creates much more interest in students, and provides for a much more interactive and engaging lesson. While a good interactive lesson can be time consuming to perfect, it does appear to be well worth the effort.

V. Technical Issues

The theory behind designing an effective computer lesson is only half of the work. In order to implement the design, a variety of technical issues must be faced. This is especially true for a web-based lesson, since the main goal is to produce a lesson that can be accessed on any computer regardless of platform or location. With the benefits of using JavaScript and HTML, come some limitations on what can be done in a lesson.

Since an effective lesson needs to be highly interactive, it is necessary to provide a way for the student to input answers into the web lesson. The simplest way to provide input is through the use of form elements such as buttons. When a certain button is hit, which corresponds to a certain option or answer to a question, an action is performed by the lesson. To implement a button which sends the student to a new page, a JavaScript function is defined in the head of the HTML document. For example:

```
<SCRIPT language="JavaScript">
function NewPage(Page) {
        location=Page;}
function OpenPage(Page) {
  var NewWindow = open(Page, "NewPage",
     "width=400,height=300,status=no,toolbar=no,menubar=no");}
</SCRIPT>
```

will declare the functions NewPage() and OpenPage(), which can be called by adding code to the body of the HTML document. For example:

```
<FORM>
<INPUT NAME="Yes" TYPE="button" value="Yes" onClick="NewPage('ans02.htm')">
<INPUT NAME="No" TYPE="button" value="No" onClick="OpenPage('ans01.htm')">
</FORM>
```

will create a button titled “Yes”, which will call the function NewPage() when clicked, and send the student to the web page “ans02.htm”. Another button titled “No” will also be created, which will call the function OpenPage() when clicked, and a new window will be created with the page “ans01.htm” inside it. The power behind JavaScript lies in the fact that these functions will work just as easily on a Mac as they would on a PC. To some extent, programs can now be created in a way that will work on any computer with a JavaScript enabled browser.

Beyond buttons, multiple choice and fill in the blank questions can also be implemented with simple JavaScript functions. These functions work great for creating a quiz, or for providing a quick assessment of a students understanding during the lesson. Unfortunately, more detailed types of inputs have their limitations.

Essays are easy to implement, but there is really no practical way to provide immediate useful feedback to an essay question. Ideally, the lesson would be able to read an essay and provide an appropriate feedback based on the essay’s content. Some physics programs, like FreeBody[8], come close to this, but programming such a function in JavaScript would be impractical. Responses to essays can still be stored or e-mailed for later evaluation though, and thus they can still be part of an effective lesson.

The most advanced interactive elements that can be implemented in web based lessons are Java applets. Java applets can provide high level programming power, and in the force lesson created for this paper, an applet named Animator[9] was used. This applet is essentially a program that displays animation based on various inputs received from the student taking the lesson. The applet contains various methods which can be called by JavaScript functions. Thus, a JavaScript function can be created which will run the Java applet based on certain parameters when called. For example:

```
function prob1()
{       F = document.data.force.value;
        m = document.data.mass.value;
        document.Animator.deleteAll();
        document.Animator.reset(0);
        document.Animator.setTimeInterval(0,2.0);
        document.Animator.setPixPerUnit(25);
        document.Animator.setGridUnit(0.1);
        document.Animator.shiftPixOrigin( -89,-75);
        document.Animator.setShapeCoord(0);
        document.Animator.setShapeRGB(0,0,0);
        document.Animator.addArrow(8, 0, "0", "0");
        document.Animator.setShapeCoord(1);
        document.Animator.setShapeRGB(255,0,0);
        xFunction = "0.5*("+ F +"/"+m+")" + "*t*t";
        document.Animator.addRectangle(20,20,xFunction,"0.35");
        document.Animator.setShapeCoord(0);
        document.Animator.setShapeRGB(0,160,0);
```

```
        arrowsHComp = 0.5*F;
        arrowsVComp = 0;
        arrowOffset = 0;
        arrowsXEq = arrowOffset+"+"+"0.5*("+ F +"/"+m+")" + "*t*t";
        document.Animator.addArrow(arrowsHComp,arrowsVComp,arrowsXEq,"0.35");

    document.Animator.setCaption("Slide 1");
    document.Animator.forward();
    document.Animator.pause();
    document.Animator.stepForward();
    document.Animator.reset( 0 );}
```

is the JavaScript function prob1(), and when called it will run the Animator applet. In the force lesson, values for the variables F and m were entered into text fields on the application page of the lesson. Then, with a click of a button, the JavaScript function prob1() was called, and an animation was displayed of an object with mass, m, moving due to a force, F. This is one example of the interactive power of Java applets. Java can provide a true platform independent programming environment, which can be completely interactive with the user, and easily posted on the web. Eventually, this will lead to the ability to put any program, no matter how complex, on the web in a form that can be used on any computer platform.

With all things considered, JavaScript and Java Applets appear to hold the key for the future of interactive computer based physics lessons. By combining the multimedia capabilities of today's web browsers, with the platform independent programming abilities of JavaScript and Java, almost any type of interactive lesson can be created and posted on the Internet. There are some limitations and unresolved compatibility problems, but there is every indication that these problems are only minor and temporary. In the future, students will be able to work on a lesson in a computer in a lab, and then study that same lesson late at night from there personal computer without noticing the slightest difference.

VI. Conclusion

Technology has greatly improved the methods and educational opportunities available in the physics classroom. Computer based lessons have evolved so that students can experience more than they could in a traditional lab, in an interactive environment that promotes a new level of understanding. By utilizing the web, JavaScript, and Java, lessons can be made available to virtually anyone on virtually any computer. While there are some limitations which hold web based lessons back, the future certainly looks promising, and the continued development of web based lessons will surly lead to a new physics experience for many students.

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