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THE VISUAL PHYSICS ADVANCEMENT PROJECT

An Interactive Qualifying Project

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By

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1. Physics
2. Education
3. Teaching

Abstract

The utilization of visual methods of education such as movies and computer animations can bring great benefits to an introductory physics course. This IQP will analyze research that supports the above hypothesis as well as propose changes to the introductory physics program at WPI to implement such methods.

Preface

Although this IQP is submitted independently, the work contributed to the the Visual Physics Advancement Project (VPAP) also includes an IQP by Colin Marker (to be completed in B term of 2004) and an MQP by Rachel Nasto. The purpose of this report is to contribute a qualitative aspect to the VPAP. The primary focus is on analysis of information obtained from various literature and interviewing physics professors at WPI as well as the investigation of feasible options for changes in the curriculum. Analysis of data is not included in this report.

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1. Introduction

At Worcester Polytechnic Institute, almost every student will at some point take the class designated PH 1110, titled “General Physics – Mechanics.” This class, often referred to as a “freshman class,” is recommended to the majority of new students who come to WPI as one of the first classes they take as it is a required class for several different majors, being a class whose fundamentals are applied in all types of engineering. Therefore, an important consideration is the amount WPI students who should succeed in gaining an understanding of concepts in introductory physics. The objective of the Visual Physics Advancement Project (VPAP) is to determine a change to WPI’s introductory physics curriculum that will result in a higher number of students passing the class with an unchanged breadth of material being covered. The general type of modification that the VPAP is intended to implement is to increase the amount of visual methods involved in physics teaching. This would be done through popular media, such as movies and computer animations. Much research was needed to determine the options available for methods of changing the curriculum as well as the practicality of making such changes.

The beginning of my work with the VPAP was C term of 2004, when I joined Colin Marker and Rachel Nasto. As I was replacing member of the group who could no longer continue, the project was already in progress. The project they had formed involved presenting movies for physics classes and presenting the classes with physics problems based on scenes from the movies. There are multiple benefits that these movie sessions are intended to exhibit. One is that the the atmosphere in which the movies are presented is an enjoyable one for the students, which may cause them to be more comfortable in participating. Another benefit is the idea that the presentation of these movies attracts the studets' attention as movies are a part of our culture to which most individuals enjoy being attentive. This attentiveness could therefore cause students to be more participant in solving or attempting the problems. The most important benefit to the movie sessions is that which relates to the overall premise of this project: they present physics concepts visually, enabling students to better understand how these concepts apply to real-life situations.

After C-term of 2004, it was no longer logistically convenient for the three members of the VPAP to remain a group and we divided after agreeing on a component of the project that each of us would complete as an independent project. Colin's IQP involves creating a website that serves as a helpful tool for collecting and storing data. Rachel's project is a physics MQP involving the analysis of the data obtained from the movie sessions. My IQP has been focused on the analysis information obtained through research of literature and further investigation of possible changes to the curriculum aside from what the VPAP had already been testing. Pertinent information found in the area of psychology will be discussed, as findings support the hypothesis that visual representaions of concepts can be beneficial to a student's understanding of the material being taught. Other literature I have reviewed in the area of educational reform as well as interviews with members of the physics faculty at WPI have provided important information and considerations that need to be taken. Investigation of available options for change in the curriculum has reveiled a form of visual representation of physics that due to affordability and convenience is a potentially beneficial change to the curriculum.

2. Literature Research.

The selection of literature I have reviewed and later analyzed is certainly diverse. Literature in the area of education, specifically educational reform, has provided important information regarding universal issues involved in changing a curriculum and such issues should be considered in this project. I have also examined literature in the area of psychology, the information from which is strong evidence in support of the idea of visual representation being beneficial. My review of publications in the subject of physics education has made apparent the potential of Physlets as a feasible implementation for the PH 1110 program.

Valuable information and ideas have come from previously completed litereratue. Multiple sources , including a past IQP student, the Carnegie Commission on Higher Education, and the Massachusetts Department of Education. Although none of these sources were related to physics education. One of the main points that relates this project is the issue of unwillingness of professors to adapt to new opportunities for teaching that arise due to technology. This literature has revealed the universality of such in issue, which presents explanations of possible issues in altering the physics curriculum at WPI.

2.1. General changes in education

The Need for Educational Reform, by Elizabeth Hogan, was an IQP involving a student teaching for 8 weeks at Wachusett High School to study the need for educational reform. This was based upon extensive research done on education reform by the Massachusetts Department of Education, Dr. Theodore Sizer, and the National Council of Teachers of Massachusetts. Hogan chose to use a new mathematics curriculum called the Interactive Mathematics Program (IMP).

The IQP report begins by describing the Massachusetts Education Reform Act, which was signed into law on June 18th, 1993. Hogan's interpretation of the law is that students shall be in a safe and enjoyable learning atmosphere, resources shall be adequate for a high level of education, specific goals for every child should be established, and educators will be responsible for a monitoring process of these goals.

The IMP curriculum, according to Hogan, "…is problem centered integrated, it expands the scope of high school mathematics, and it includes long-term, open-ended investigations.[1]" This is intended to encourage students to think of mathematics in terms of its applications. There is actually a common trend between this particular project and my own: a method of stimulating students' interest in a subject matter by emphasizing the consideration of its applications.

Hogan then describes the new role of the teacher in the IMP, a role requiring teachers to be observers and listeners, describing their duty to "…ask students questions in order to provoke students to do their own thinking. Students can no longer be hand fed

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[1] Elizabeth Hogan, "The Need for Education Reform" (IQP, Worcester Polytechnic Institute, 1999), 19

information; they must be able to solve problems on their own.[2]" This can also be related to the VPAP because our sessions mainly involved us displaying the movies and presenting the problems, then having the students solve the problems on their own while giving subtle hints when they appeared to be stuck.

It was very interesting to read this report as even though the focus was on high school math and not necessarily focused on the advantage of visual education, it still emphasized points similar to those stressed by the VPAP. The implementation of technology and the use of problems dealing with real-world situations are examples of such points. The information learned in this IQP can help in strengthening the statement of mine.

The Fourth Revolution: Instructional Technology in Higher Education By The Carnegie Commission on Higher Education is concerned with the utilization of technology in instruction. It states that the benefit of technology is the greater flexibility and more options that it offers students. It is pointed out that many faculty members tend to be apathetic to the potential present in instructional technology, and the book emphasizes what is required to fully realize the advantages of implementing technology in education. Although this book was written in 1972, and much advances have occurred since then, many of the concepts mentioned are still useful and it is interesting to compare what they have predicted to what has occurred.

The book starts with a list of major themes and observations. One that stood out was the statement on the main advantages of information technology. "For students, the expanding technology has two major advantages: properly applied, in increases the opportunities for independent study, and it provides students with a richer variety of

[2] Elizabeth Hogan, "The Need for Education Reform" (IQP, Worcester Polytechnic Institute, 1999), 19-20

courses and methods of instruction.[3]" The authors are pointing out that students can choose between the techniques of lecture and information technology for instruction, creating competition and therefore raising the quality of both. Then the authors move on to mention two major issues in education:

> ...two complaints of students are the inadequate variety of courses available to them and the lack of quality in some classroom instruction. The expanding technology can speak to both of these complaints. It can also help supple to the two great aspects of 'humanization' of higher education (1) by making access easier and (2) by paying more attention to the specific needs of individual students.[4]

In a later chapter, the authors discuss the impacts that instructional technology will have on faculty. They make a statement that the impression that teaching-learning media will replace the professor making him or her obsolete is incorrect. However, the authors do believe that the role of the professor will be significantly changed. "To prepare fully for the new faculty roles, prospective college and university teachers should ideally have training and experience in instructional development and the use of the new technology prior to their first academic appointments.[5]" The book is illustrating the need for faculty to be as up-to-date as possible. Although what was "new technology" when this book was written is no longer new, the need for professors to be well versed in new technology still exists as technology continues to advance.

Although this book is outdated, it contains a good deal of facts and opinions that can be pertinent to the Visual Physics Advancement Project. For one, it describes the advantage of information technology being more flexible. It is interesting to realize this advantage, as it has not been very much discussed in our project but is very much present in what we are creating. Also, as mentioned above, the need for professors to continue to

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[3] The Carnegie Commission on Higher Education. *The Fourth Revolution: Instructional Technology in Higher Education.* (Hightstown, NJ: McGraw-Hill Book Company, 1972), 2
[4] Carnegie, *The Fourth Revolution,* 3
[5] Carnegie, *The Fourth Revolution,* 68

keep up with technological advances is still important. This can be related to the idea discussed in our project regarding the generation gap between students and professors being the cause of much lack of understanding by the students, who are more accustomed to recent technology than the professors are. The Carnegie Commission on Higher Education is a much useful resource for ideas on educational reform.

2.2 Methods of Visual Physics Education

2.2.1 Physlets

Physics Applets, which have been given the name "Physlets," are small applications written in the java language that run in browser software. They are designed to display physical concepts with simple animation. They are extremely flexible since they are controlled by Javascript and can easily be made available on the web. I decided to research Physlets to determine how they operate, what is needed to utilize them, and how they can be implemented in introductory physics instruction.

A major source of information on Physlets can be found at the "Physlets Home" Page" as part of Davidson College's Physics department website. The URL is http://webphysics.davidson.edu/Applets/Applets.html. This website, which contains hundreds of Physlets available and publicly permitted for download, is run by Wolfgang Christian, who has been credited with the original creation. This website, along with many others which can be located simply by entering "Physlets" in a search engine, a wide range of Physlets, covering essentially every common topic of introductory physics.

The figures 2.1a through 2.1c represent an example Physlet taken from the Davidson College website. This is a Physlet that is intended to represent oscillation, a general topic in the area of physics that involves movement of an object first in one direction and then back again in the opposite direction. This particular example illustrates such a concept through a generic instance of oscillation: a ball attached to a spring. The user is given the option of the type of oscillation to be demonstrated as well as the starting point of the ball. The type of oscillation selected in the case depicted by figures 2.1a through 2.1c is damped simple harmonic motion.

Simple harmonic motion is a particular type of oscillation with a force that is always opposite and proportional to the object's distance from its equilibrium position. An object in simple harmonic motion will theoretically continue to oscillate back and forth indefinitely,

Figure 2.1a shows the Physlet in its default status, in which the ball is in equilibrium position. This Physlet is particularly interesting due to its two displays; the object in motion as well as the plot if its position and velocity can be watched simultaneously. The user of this Physlet is given the option of whether or not to have the velocity plot shown as well as the ability to input the As indicated with the text "drag me" displayed over the ball, the user can use a computer mouse/curser to move the ball to the starting position desired. The user would then select the "run" button under the graph to begin the animation.

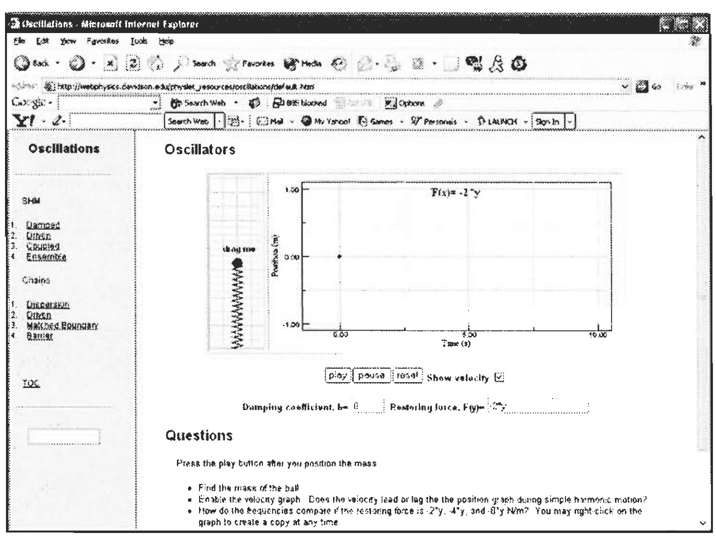

Figure 2.1a: Physlet demonstrating Simple harmonic motion[6]

Figure 2.1b shows the state of the Physlet after the user has placed the ball at a starting position of one meter above its equilibrium position, and then run the animation

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[6] Davidson College. "Oscillations." *The Physlet Resource.* http://webphysics.davidson.edu/physlet_resources; (15 Sept. 2004)

for 5 seconds. The image of the ball and spring then becomes animated as the ball oscillates, and the position of the ball is then graphed with respect to time as this motion occurs. Figure 2.1c displays the same situation except that that the user has specified that the velocity shall all also be plotted.

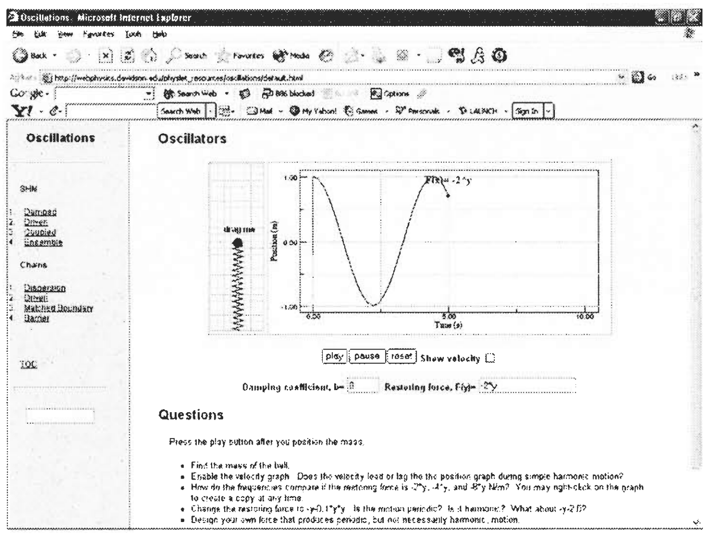

Figure 2.1b: Simple harmonic motion, after approximately 5 seconds[7]

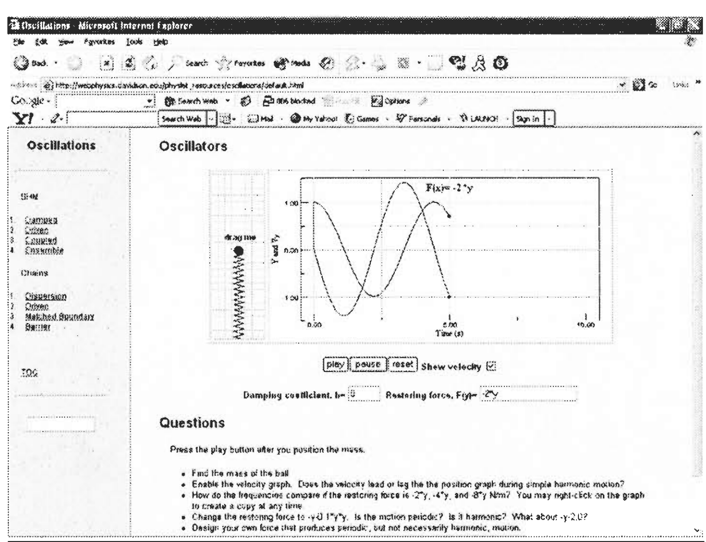

Figure 2.1c: Situation similar to Figure 2.1b, now displaying velocity[8]

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[7] Davidson College. "Oscillations." *The Physlet Resource.* http://webphysics.davidson.edu/physlet_resources; (15 Sept. 2004)

This is an example of Physlets that can be utilized as an aid in teaching of introductory physics. It is presented with a series of questions that can be given to a student using the applet that resemble questions that are commonly given to students to demonstrate understanding of concepts involved in the topic of oscillation. The usefulness of Physlets as illustrated in this example is that they're a good way to obtain an understanding of how physics concepts are applied. Students using Physlets can see motion taking place as it relates to material they are learning in lecture. In the above example, a student can witness the ball moving back and forth and its position and velocity being simultaneously plotted and this would be a representation of the mathematical concepts that this student is learning in a course. Physlets like this one can be beneficial to an introductory physics program and studies have been performed to determine the best ways of using Physlets for instructional purposes.

A Comparison of Inquiry and Worked Example Web-Based Instruction Using Physlets by Kevin M. Lee, Gayle Nicoll, and David W. Brooks is an article that discusses a study done at the University of Nebraska – Lincoln. It concerned a class designated Physics 151, a semester course which is an algebra-based overview of physics covering mechanics, thermal physics and electricity.[9] This study involved 10 units of instruction, termed "excursions", involving web-based instruction followed by a web-based assessment with two problems.[10] Two different forms of web-based instruction were used: Inquiry and Worked Example, and half of the students were assigned to each.

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[8] Davidson College. "Oscillations." *The Physlet Resource.* http://webphysics.davidson.edu/physlet_resources; (15 Sept. 2004)

[9] Kevin M. Lee, Gayle Nicoll, and David W. Brooks. "A Comparison of Inquiry and Worked Example Web-Based Instruction Using Physlets." *Journal of Science and Technology* 13 (2004). Journal on-line. Available from http://www.kluweronline.com/article.asp?J=4947&I=29. Accessed 22 April 2004

[10] Lee, Nicoll, Brooks, 83.

The Inquiry protocol involved excursions that generally consisted of three Physlet animations. They included selection menus, allowing students to control the input parameters to the simulations and to control the input parameters to the simulations and output boxes that listed the values of certain variables[11]. Article displays an example involving a ballistic pendulum, which consists of a wooden block suspended by four cables, which is shot and swings upward as a bullet becomes embedded in it. Students were allowed to specify the initial velocity of the bullet, the mass of the bullet, and the mass of the block. The velocity of the block and bullet combined after impact, the vertical height of the upswing, and the kinetic energy "lost" in the collision were given as outputs. Students were asked to make predictions regarding other choices of input parameters and to run the simulation and perform calculations for those values. My main criticism is the large number of parameters that can be controlled by the student. I feel that most students would prefer most of these parameters to be predetermined so that the first thing they do is watch the animation rather than concern themselves with the input parameters.

"The Worked Example protocol typically consisted of six Physlets, grouped in pairs, which were identical in format to each other and matched a Physlet in the Inquiry Protocol. However each Physlet in the pair had different simulation parameters which spanned the selection range from the corresponding Inquiry Physlet. Calculations of the output variables of interest were completed for each of the paired Physlets.[12]" To summarize the main difference between the two protocols, the Inquiry Protocol involved parameters input by the student while the Worked Example Protocol involved

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[11] Lee, Nicoll, Brooks, 83.
[12] Lee, Nicoll, Brooks, 84.

predetermined parameters. The authors point out that unlike the Inquiry Protocol, no prompts were given requesting students to think about various concepts and relationships. A Physlet concerning the same ballistic pendulum situation except that it is not in the Worked Example Protocol. I personally had preference upon first seeing this example due to its simplicity. A student using this Physlet can still receive the same aid in understanding from this Physlet as the one in the Inquiry Protocol with having to spend the time deciding and specifying the input parameters.

The study resulted in the Worked Example group performing significantly better than the Inquiry group, with an average score of almost 12 points (out of 100 higher). Another interesting difference is that between the agregrate GPAs for the course. To explain these results, the authors feel that when students are given the ability to control parameters in a simulation, as in the Inquiry protocol, they repeatedly change these parameters to see the different outcomes, while in the Worked Example protocol they are forced to observe systematic trends. The article is concluded with a statement that because of these differences, "Students in the Worked Example group scored significantly higher than students in the Inquiry group. Thus, there was no apparent development of physical intuition or superior problem solving ability associated with Inquiry techniques such as the capability to experiment with simulation parameters and being asked to make predictions and reflections.[13]"

This article does not prove or disprove whether Physlets are beneficial, but rather makes a suggestion for an effective way in which they should be presented. The implications of this article are that when Physlets are implemented in instruction, they are most beneficial when students are not given the opportunity to input various parameters.

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[13] Lee, Nicoll, Brooks, 87.

It is best when students are presented with Physlets with a predetermined set of parameters, asked to analyze the situation and answer questions based on these parameters, and then asked to intuitively predict how the situation would change had the parameters been different.

What I have found is an extremely useful tool in that is certainly a possibility for a new form of visual instruction in PH 1110. Physlets are easy to use and economically feasible. They are also very versatile. Physlets can cover a wide range of physics topics ranging from a block on an incline plane to quantum mechanics. Physlets have great potential and definitely should be at least considered for implementation into a curriculum at WPI.

2.3.2 Physics Academic Software

Physics Academic Software is a company that reviews, selects, and publishes software for high school, undergraduate, and graduate education in physics. I decided to consider this company to determine if its services are of interest to the VPAP. There are particular programs published by this company that seem to have potential for use with PH 1110. However, these programs are also costly and therefore would be difficult to implement.

Mechanics in Motion is an example of a useful program published by Physics Academic Software. This is a simulation-based program that allows the user to select from a variety of topics in physics and input data from which a simulation will be created. A screenshot provided on the company's web site at the URL http://webassign.net/pas/mechanics_in_motion/mim.html. This screen shot displays the data input features of the program when used to simulate projectile motion. Judging by this, it appears that the range of preferences that can be specified by the user is reasonably broad.

A positive characteristic of this program is its versatility as it can simulate a wide variety of situations. Also this when the simulation occurs, the program displays a wide selection of variables that involve multiple concepts, i.e. it analyzes the motion in both the Newton's laws approach and the work-energy. A major downfall of this program is that it is highly expensive. A 10-copy package of this software costs $400, so to have conference of approximately 30 students using this program would cost $1200. It is my opinion the features of this program are not worth such a cost when Physlets can be downloaded for free.

2.4. Research in Psychology

To support the possibly advantages of visual representation in education, that students have a need to learn from visual stimuli, I have done some research in psychology and its implications on this topic. The information I have found shows evidence of impressive capabilities that visual stimuli have in both memory and perception processes that occur in the human mind.

The book Cognitive Psychology for Teachers by John Glover, Royce Ronning, and Roger Bruning specifically mentions the ability of visual representations in education to bring about great results. One section of the book includes a statement on the concept of presenting information both visually and auditorily. "Given the limits of students' ability to hold information in their sensory registers, we would expect that information presented both visually and auditorily would have a higher likelihood of being perceived than information presented in only one format. Hence, the use of visual aids for auditory presentations and discussions accompanying visual materials seem to be reasonable approaches to increasing the likelihood that instructional materials will be perceived.[14]" To clarify the terminology, the sensory register is the very first stage of memory which only briefly holds This is certainly a statement that further shows that what the Visual Physics Advancement Project is intending would be helpful as, for example, a computer animation representing a physics concept could easily be presented in junction with auditory instruction from a professor in an everyday class at WPI, creating exactly the stimuli that these psychologists have stated will improve perception of concepts.

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[14] John Glover, Royce Ronning, and Roger Bruning, *Cognitive Psychology for Teachers* (New York : Macmillan, 1990), 35.

This book discusses the important points for teaching science as being to "(1) reveal and understand student preconceptions, (2) create conceptual conflict with those preconceptions, and (3) encourage the development of revised or new schemata about the phenomena in question.[15]" This section of the book discusses a study on elementary school students involving the teaching of the particle theory of gases. The book describes that these students were presented with a flask and a vacuum pump and were told that the vacuum pump drew half the air out of the flask. They were then told to imagine that they had the ability to see the air remaining in the flask and were asked to draw a picture on the chalkboard of the air remaining in the flask. Here is where it relates my project. Although these authors are mainly stressing the importance of revealing student preconceptions, this is in fact an example of visual representation. "The drawings and explanations generated by the class are posed as alternatives to whatever view each child holds.(If it happens that the 'correct' or 'scientific' view is not posed by the children, the teacher may wish to supply it as one given by a student in another class.)[16] In this case the students are required to create the visual representations on their own and then can see what they have done to understand whether they are correct.

Another section of the book discusses imaginal representation in memory. In this section, Glover, Ronning, and Bruning discuss the abilities that the human mind has for recalling visual events, and cite studies that have demonstrated such capabilities. "...Standing, Conezio, and Haber (1970), in an early study of visual recognition memory, showed subjects 2,500 slides for 10 seconds each. Recognition, estimated from a test on a

[15] Glover, Ronning, and Bruning, *Cognitive Psychology for Teachers,* 344
[16] Glover, Ronning, and Bruning, *Cognitive Psychology for Teachers,* 345

subset of these slides, was over 90 percent![17]" The authors then proceed to discuss theories by Alan Paivio.

Alan Paivio is a psychologist who has demonstrated the benefits of visual images on learning and memory. One of his main contributions is the dual coding theory. This theory deals with two systems which information is received by the human mind be two systems: the verbal coding system and the imaginal coding system. The verbal coding system is what the mind uses to encode information such as words, sentences, and stories. The imaginal encoding system is used to encode pictures sensations, and sounds.[18]

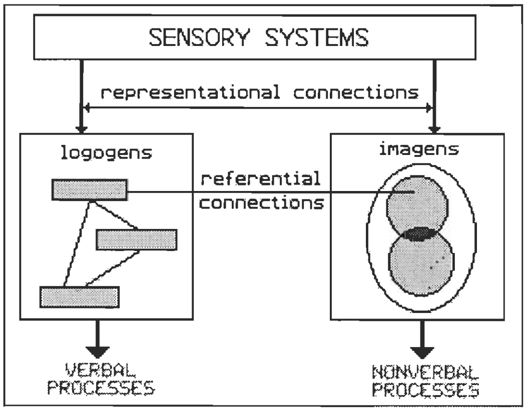


Figure 2.2: Model of Paivio's imaginal encoding system[19]

Paivio's dual coding theory states that these two systems are actually interconnected. Due to this interconnection, memory is enhanced when information is coded into both systems, while memory that is only coded in only one of the two systems will be more easily forgotten. This is related to the concept of using multiple forms of communication in instruction as when a student is presented with a concept both visually

[17] Glover, Ronning, and Bruning, *Cognitive Psychology for Teachers,* 65
[18] Glover, Ronning, and Bruning, *Cognitive Psychology for Teachers,* 66
[19] Greg Kearsley, *Dual Coding Theory (A. Paivio)* [on-line]; available from http://tip.psychology.org/paivio.html; Internet; Accessed 12 September 2004.

and auditorily, that student is perceiving the information in both of his or her coding systems.

Though Paivio has been cited as having hypothesized that nonverbal components of memory traces are generally stronger than verbal memories, I have not found significant literature that cite evidence he has presented to support this hypothesis. However the information I have found about Paivio's findings suggests benefits involved in utilizing both visual and audio representation of material. Paivio's findings have implications regarding benefits involved in the balance of visual and instructional teaching which the VPAP is intended to achieve.

3. Interviews

I have interviewed four professors in the Physics department at WPI, who will remain anonymous. I asked each of them the same set of questions regarding their opinions of the subject matter. There were a couple of common themes, but the responses were varied enough to obtain a good spectrum of ideas. The questions were as follows:

1. What do you feel is the main problem in the area of physics education today?
2. In your opinion, how has the development of technology in our society affected the learning styles of students?
3. Do you feel that change is necessary to accommodate this?
4. The Visual Physics Advancement Project suggests a form of physics education that involves utilizing computer graphics and popular media as forms of visual instruction. If such a system were implemented, what do you feel will be the result?
5. Do you think that implementing a program is feasible? What are the ramifications?

To the first question, professors A and B responded stating that the main problem with physics education is getting the students interested. One particular statement from professor A was, "I think there needs to be more of what's called active learning – students actually *doing* something in the classroom instead of blindly sitting there and taking notes." This professor felt that for students to take an active role in what they are being taught is crucial to getting them interested. Professor C felt that a significant problem was getting the students to keep up. This professor stated one of the biggest challenges of the professor is, "to try to coax students into, in some manner, come into grips with the material, so that the days don't go by, day after day, where they don't actually think at all about the physics." This professor referred to daily work as the ideal way of keeping a student engaged with the material. Professor D felt that the biggest issue is the ability of the professor to successfully communicate the material.

To the second and third questions, I got varied responses. Professor A feels that technology has affected students in that they now read less than they used to. "I've noticed recently that students with whom I've had conversations about leisure reading have no trouble following written instructions for an assignment. This is entirely anecdotal. And students with whom I haven't had conversations about leisure reading tend to be ones that don't pay careful attention to written instructions." This professor followed this up by responding to the third question by stating that while students should learn to read instructions carefully, reaching them in the most efficient way possible is crucial so it is important to have a balance of multiple approaches to the material. Professor D pointed out that Students now have less hands-on experience with things that professors attained when they were younger (ex. Working on a car engine, etc.) and that this can influence their ability to understand how some things occur in the physical world. This can be related to professor A's statement about the need for more active learning, as the increase in the amount of active learning can make up for this decrease in working with their hands.

The fourth question, which was an important one, brought Professor A to state that it would be helping some students while hindering others and that a certain method of getting material across should not entirely replace another. Even though Professor A did not clarify why this new form of education would hinder certain students, my interpretation is that this professor feels that a method of teaching that is strictly visual would be detrimental and that multiple forms of representation should be present. Professor B responded optimistically, saying that this type of program would have positive results if indicated. Professors C and D basically said that they could not predict what the outcome would be.

To the final, and probably most important, question, every professor had basically the same response. They all felt that the implementation would be difficult just because it is such a dramatic change. A common theme in the responses to my questions was in fact the idea of professors not wanting to make a large change to the traditional methods that they have always used. Common trends can be seen between the responses to the interviews and a lot of the research I have done in education, which discussed this particular issue as a global one. One professor pointed out the fact that the term system at WPI limits a particular course to 28 contact hours and these 28 contact hours need to be planned out specifically. This would make said educational program difficult to implement at WPI because it is difficult for a professor to get away from familiar patterns since the program is so scripted. This is the major obstacle that may hinder the goal of the VPAP from being achieved: the hesitation of the faculty to dramatically change the curriculum to which they are accustomed.

4. Analysis of Research

The research I have performed has given adequate information to reaffirm the benefits of implementing visual communication in education. This section will include my interpretation of such literature and conclusions of the importance of visual education and how it applies to introductory physics of WPI. I will also discuss in this section the current state of how general physics is taught. Finally, this section will examine the possible changes that can be made to benefit the curriculum and what is required for such changes.

My interpretation of the research that I have done has also led me to some conclusions regarding both education in general and to the educational system specifically proposed by the Visual Physics Advancement Project. I have further supported the claim that more visual representations of concepts in introductory physics would be help students in understanding such concepts. I have also come to the conclusions that the advancement of the implementation of technology and more visual representation in education requires the effort of faculty in adapting to any new methods and that one of the main issues regarding adopting a more visual form of physics education at WPI is that of the professors being willing to modify on the traditional methods that they have been using for years. Finally I have formed my own ideas on what changes can be made to benefit such an educational program.

4.1 The Importance of Visual Representation

A significant portion of my research has given support to the hypothesis that implementation of additional visual representations of concepts in PH 1110 can be greatly beneficial. Specifically, research I have done in the area of psychology has given support from a scientific standpoint that when an individual is presented with a concept both visually and auditorily, he or she is far more likely to understand the material than if it were received through one type of stimuli. Also, studies have proven that visual aids in education result in greater amounts of information retained in memory.

The information I have obtained through my research demonstrates the importance of visual stimuli in students' learning processes. Though the original statement of the Visual Physics Advancement Project implied that the advantage of visual learning was present more in present-day students than in current professors when they were students, I have formed the belief that such an advantage can be caused by pure nature of human psychology, regardless of the generation.

The sources that I have researched have mentioned the benefit of presenting information that will be received in multiple (i.e. visual and auditory) forms of stimuli. As mentioned in my citation of Cognitive Psychology for Teachers by Glover, Ronning, and Bruning, the simultaneous representation of concepts in both visual and auditory forms increases the likelihood that the material will be understood. This has to do with the capacity of the human mind to hold information in their sensory registers. When a student is receiving information both visually and auditorily, his or her mind has the ability to make connections between the visual and auditory information and this causes the information to be more easily understood. The mind no longer has to focus its attention on creating the visual images based on the auditory information, as it is not receiving the visual image externally. As the need for such a cognitive process is eliminated, the mind can now focus on the interpretation of the information received and the encoding of the information into long-term memory.

Additional support for the benefit of simultaneous visual and auditory communication comes from the work of Alan Paivio and his dual coding theory. According to this theory, because the verbal and imaginal coding systems are interconnected, information is recalled better when it is coded in both systems. This means that when an individual is presented with information both visually and auditorily, both systems of memory are being utilized, and the connections formed between the visually and auditory representations of the information assist in recalling the information.

A component of the cognitive processes of the human mind that has immense capabilities is visual recognition memory, the way in an individual recalls information about visual events. Numerous studies, including the aforementioned 1970 study by Standing, Cenezio and Haber, have shown the ability of the human mind to recall thousands of images that were at one point perceived. This psychological capability is certainly one that should be utilized in any classroom.

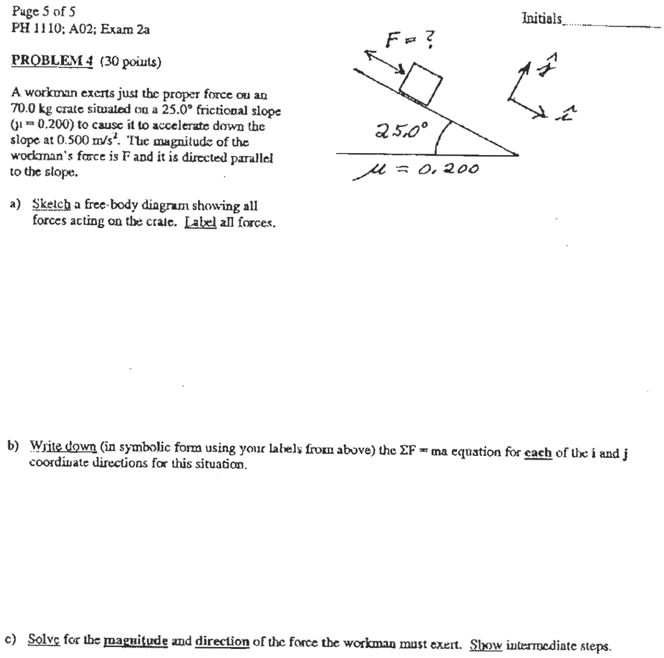
Upon joining the project group working on the Visual Physics Advancement Project, I was presented with a previously formed hypothesis that contemporary students, because they have grown up in a more technologically advanced society, have more visual learning style than current professors had when they were college students. More specifically, the statement was that because the current generation has grown up surrounded by media such as movies, video games, and computers, that they now are more accustomed to obtaining their information through visual stumuli, rather than through reading comprehension and listening skills, through which more information was obtained in previous decades when less of such media was available. Although this statement may be true, the research I have conducted has neither supported nor disputed such a claim. The information that I have gathered through my research concerns the advantages of visual education simply as it relates to human nature. Therefore, I have changed viewpoints regarding the benefits from discussing them as they relate to different generations to advocating the advantages of visual communication in education overall, regardless the age of the students or professors. With the evidence I have found from a psychological level, I have assumed the standpoint that visual representation has always had advantages in education, though this idea may have become more apparent with the advancement of popular media.

4.2 The Current Status of the Curriculum

As a WPI student studying mechanical engineering, I have taken PH 1110 and have an understanding of the methods in which it is currently taught. Currently, concepts are presented mainly verbally, and although visual representations are presented, they generally are not ones that fully utilize the potential that visual communication has. Sample problems that are currently involved in the course can be examined to determine how students' understanding of the concepts involved can benefit from a different form of instruction.

A lecture in PH 1110 at WPI generally involves the professor drawing a simple diagram to represent a concept and verbally explaining the concept and solving it on a blackboard. Though these lectures do in fact involve visual representations of the concepts that are being taught, this project is focused on visual representations that are animated, so that they demonstrated the motion involved in a problem rather than the state of the objects in one instance.

An example of a concept that can be more effectively taught via visual communication is involved in the sample exam problem depicted below. This is from an exam in PH 1110 at WPI that was administered on September 27th, 2002. It is an example of a very common type of basic physics problem involving a block placed on an inclined plane in which the student is asked to draw a free-body diagram, calculate the work done by forces other than friction as the block slides down the plane, and calculate the work done by friction. The way in which visuals can benefit the understanding of the concepts involved is simple the ability to see exactly what motion results from the equations involved. Work is one of the fundamental concepts in mechanical physics. Note that is so that regardless of whether or not visuals are implemented, the exam content would not be altered. The question of regarding the benefit of visuals can now be addressed in the form of an example scenario involves a student who does not by any means have the natural talent for physics. Compare this student's chances of passing if 1) he went to the lectures all week as well as a typical PH 1110 conference or 2)if he went to the same amount of lectures and one of his conferences was replaced with a movie session that involves a situation similar to the problem in Figure 4.1. In my experience, the movie sessions involve just as much opportunity for questions and review as a normal conference meeting. It is not definite that this student's chance of passing will be increased by the movie session. However, there does not appear to be any way in which they could be reduced.


Page 5 of 5
PH 1110; A02; Exam 2a

Initials________

PROBLEM 4 (30 points)

A workman exerts just the proper force on an 70.0 kg crate situated on a 25.0° frictional slope (μ = 0.200) to cause it to accelerate down the slope at 0.500 m/s². The magnitude of the workman's force is F and it is directed parallel to the slope.

a) Sketch a free-body diagram showing all forces acting on the crate. Label all forces.

b) Write down (in symbolic form using your labels from above) the ΣF = ma equation for each of the i and j coordinate directions for this situation.

c) Solve for the magnitude and direction of the force the workman must exert. Show intermediate steps.

Figure 4.1: A problem taken from a PH 1110 exam in the fall of 2002[20]

4.3 Possible Changes to the Curriculum

4.3.1 Physlets

Physlets are interesting to investigate as a potential addition to the introductory physics program at WPI. It does not appear unreasonable to consider the possibility of utilizing WPI's computer facilities for a conference section of PH 1110. The alternative of changing the conference meetings to involve these interactive simulations is worth the attempt. Physlets are certainly economically feasible, as WPI would not be spending any more than it already is just to have Internet access.

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[20] Worcester Polytechnic Institute, Department of Physics. "Physics Courses Online." *Sample Examinations.* http://www.wpi.edu/Academics/Depts/Physics/Courses/ph1110a04/Images/ex2.pdf; (22 Sept. 2004)

communicated to students in lectures prior to the exam by presenting Physlets that simulate the block sliding down the incline. Figure 4.2 represents another Physlet courtesy of the website of Davidson College that represents exactly the same concepts at the problem in Figure 4.1. The student is not able to select and input parameters, and my findings from literature about Physlets imply that this can be advantageous. The Student can focus on the application of the equations learned into the motion that results from the given parameters.

It can be seen how Physlets can help improve understanding in concepts like this one because students can, after first learning the concepts in a lecture, then use a Physlet to then see the motion take place. In this case, a student who has first learned the concepts and equations involved in a block on an incline, relating pushing/pulling forces, friction, and resulting motion, can improve his or her understanding of them by using a Physlet like this and witness how the formulas translate into the physical world by watching the motion take place. This is a Physlet that could possibly benefit the student from the example situation previously discussed.

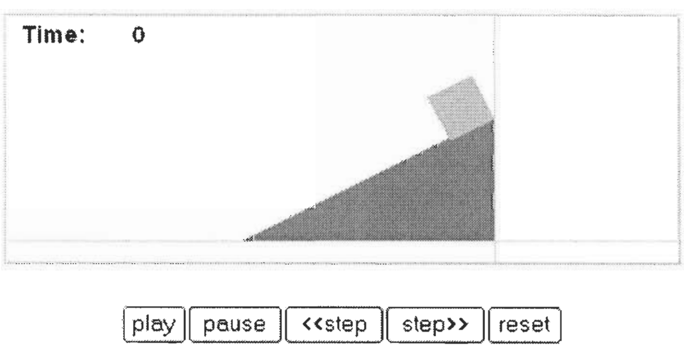


Figure 4.2: Physlet demonstrating a block and plane situation[20]

[20] Davidson College. "Oscillations." *The Physlet Resource.* http://webphysics.davidson.edu/physlet_resources; (15 Sept. 2004)

Physlets have great potential for implementation in the PH 1110 curriculum. A conference section could meet in a computer lab with each student instructed to observe a Physlet with a predetermined set of parameters and asked to calculate values not displayed by the Physlet. In the case of the Physlet depicted in figure 4.2, the predetermined values instructed to the students would be the ones for the angle of the incline, the coefficients of friction, and the masses of the two blocks. Each student would then run the animation with these given values and determine the time it takes for M2 to reach the floor. This is essentially the same type of problem that PH 1110 students are frequently asked to do in the current curriculum. With Physlets, students would still have to be learning the same amount of material, except that now their understanding of the material would be aided.

4.4.2 Movies

During C-term of 2004, the three individuals working on the Visual Physics Advancement Project conducted sessions with conference sections of students enrolled in PH1110 and presented them with popular movies. These sessions involved playing selected scenes from movies and gave students problems to solve based on these scenes. While quantitative analyses of the outcome of these sessions can be found in the MQP by Rachel Nasto as well as the IQP done by Colin Marker, this report will include a qualitative analysis of movie sessions, their benefits, and how they can be possibly be implemented in the PH 1110 curriculum at WPI.

For these sessions, groups of students taking PH 1110 were asked to meet during the evening and participate as the students involved in the VPAP played movies projected at a large screen at the front of the classroom. Approximately 15 students would show up on average. These movies were played at selected scenes and paused after the event in the movie that will be used as a basis for problems has taken place. At this time, the VPAP students would discuss what has happened in the movie and how certain concepts in physics are involved in such an event. The students would then be presented with problems that relate to such concepts.

An example of a movie that was played in one these sessions is the film "Boondock Saints." At the time of the session in which this movie was presented, the topic that students in PH 1110 were learning was **kinematics**. Kinematics is a branch of physics that deals with analysis of motion without regard to forces. It involves concepts such as how the displacement, velocity, and acceleration of an object relate to one another. This session involved 3 scenes of the motion picture, each presented with problems involving kinematics. In one of the scenes from the movie that was presented in the session, a toilet was thrown off of the roof of a building. Below is a screen shot of this particular scene, at the instant the toilet is dropped.

Figure 4.3: Scene from "Boondock Saints," when a toilet is dropped from a building[21]

Figure 4.4 shows the list of problems presented during this scene, with solutions. This is the sheet used by the three VPAP students as a reference while presenting the problems. Students were presented with a 3-part problem that required them to draw a free-body diagram of the forces acting on the toilet, determine the time it takes for the toilet to reach the ground, determine the velocity of the toilet just before it hits the ground, and decide whether the events that occur in the scene are consistent with the laws of physics. We wrote each problem on the board at the front of the room, and engaged the students by asking some to volunteer to solve the problem on the board. If students were having difficulty with the problems, we would then ask them questions and give them clues to assist them in arriving to the solutions that appear in Figure 4.4

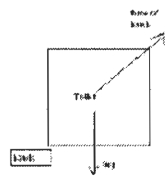
[21] *Boondock Saints.* [DVD]. (2000) Twentieth Century Fox

Kinematics

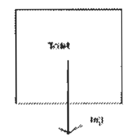
(23:14) Throws a toilet off of a building and then jumps off himself

a) Draw a free body diagram of the toilet while being dropped off the building

Before Toilet is Dropped



In Free Fall



b) If the building is 100m high how much time does it take to reach the bottom.

$y_f = y_i + v_i t + \frac{1}{2} at^2$
$0 = 100 + 0 + \frac{1}{2}(-9.8)t^2$
$0 = 100 - 4.9t^2$
$t^2 = 100/4.9$
$t = 4.51s$

c) What is the velocity of the toilet just before it hits the ground

$v_f = v_i at$
$v_f = 0 + -9.8(4.51)$
$v_f = -44.27\ ^m/_s$

d) is this consistent with the laws of physics

If the toilet falls at the same height as the top of the toilet this is not congruent with the laws of physics. No matter how light or heavy an object they fall at the same rat and therefore they should hit at the same time. This suggests that the man in the movie dropped the toilet with the tank facing downwards and held the actual toilet f a minute. Therefore yes it is congruent only if the toilet was delayed at the top was released.

Figure 4.4: Set of problems involving kinematics, presented with "Boondock Saints"

Please note that values of given parameters in all of the problems (in this case the height of the building) do not reflect the values of these parameters as that were present in the movies, or rather, the values that would be true if the events in these scenes occurred in real life. We felt that determining such values was not necessary for the purpose of these sessions, which was to improve understanding of overall concepts in physics.

There are many advantages to these sessions. One is that they capture the attention and interest in the students. Another advantage is the atmosphere in which they are presented. Most importantly, these sessions show students situations involving the concepts that they are learning in physics they can readily understand.

Students are accustomed to paying attention to events in movies. Motion pictures are a part of our culture and almost every student will have a background that includes numerous movies that they have witnessed and enjoyed. I believe that this is one of the major advantages of the movie sessions that were conducted. Students were so accustomed to movies that they had an inclination to be attentive to the scenes that we were presenting and this put them in the mindset in which they would be attentive to the problems and explanations presented afterwards. This is one of the most advantageous traits of movie sessions because while a lecture is a situation in which students often have to force themselves to be attentive, it almost comes naturally for a student to be attentive when a motion picture is being displayed.

As we conducted the movie sessions, another characteristic that encouraged student involvement was the fact that the atmosphere was one in which the students felt very comfortable. We started off the sessions by serving popcorn and soda to the students. During the time in which we were waiting for all the students to arrive, we had conversations with the students about their levels of interest and performance in physics and as problems with which we could assist them. In these conversations, we spoke to them with neither a condescending tone nor implications of expectations we had in terms of their knowledge of the material. These factors combined to create an atmosphere that was generally informal.

Some may argue that such an atmosphere may cause counter productivity as it may cause students to take the sessions less seriously. It is our opinion that while a professional atmosphere is necessary in a lecture, an informal atmosphere in sessions like these might be beneficial for those students who are weary in the lecture atmosphere as it may stimulate them to be more participant. It is my personal experience that while I spoke to these students as essentially peers, this appeared to trigger willingness to pay attention to my instruction and improved the amount which the students gained from the sessions.

The benefit of visual aids of instruction, the existence of which I have supported strongly through research, is present in movie sessions. If a student learns a particular concept in a physics lecture and then proceeds to attend a movie session, he or she is visually witnessing these concepts in the events that occur in the movie being presented. Without these movie sessions, a student may be less likely to visualize how certain concepts in physics affect real-life situations. For example, in lectures involving kinematics, students learn the mathematical relationships of velocity, acceleration, and displacement and are presented with pictures and diagrams to represent the motions related to such concepts. Despite such representations, students have to depict in their own minds the applications of kinematics concepts, i.e. a student may have a diagram of how an object will move with a given acceleration, but he or she will have to mentally depict how the motion of the object would appear if the instance occurred in real life. Difficulty in creating this mental depiction can cause this student to not entirely grasp the concepts. This is the main issue that the movie sessions are intended to resolve.

Take for example a case in which a student who attends a kinematics lecture then proceeds to attend the previously described "Boondock Saint" movie session. This student, while having knowledge of the general concepts covered in the lecture, will witness the applications in watching the movie. As the problem analyzing the kinematics in the "toilet scene" is presented, this will form connections in the student's mind between the mathematical expressions for velocity and acceleration and the motion of the falling toilet. This will help the student understand the concepts as he or she is now witnessing the way in which the mathematical equations learned in lecture are translated into real-world situations.

5. Conclusions

My portion of the work on the Visual Physics Advancement Project has given a qualitative aspect to the determination of the importance and feasibility of altering the WPI Physics course PH 1110. My research has provided much support for the statement that additional methods of visual teaching in physics could be beneficial. I have suggested possible forms of such methods and why such methods are feasible. The combination of this research and the responses I received in my interviews with physics faculty has lead me to the conclusions that the changes this project has proposed in PH 1110 have great potential of being beneficial to the program and the one factor that will prevent these changes from occurring is whether or not the professors will be willing to adjust to such a change. I feel that the students' need to adjust to a large change will be significantly less of an issue because, when compared to most professors, they are not in a state of being accustomed to the current technique.

Of the ways of including more visual forms of teaching in PH 1110 that I have researched, there are two that have stood out as both feasible and potentially beneficial. One of them is the movie sessions. As mentioned previously, quantitative (data) analysis of the results of the movie sessions would have to be obtained from the IQP of Colin Marker and the MQP of Rachel Nasto. The statements that I have made qualitatively analyze the advantages of these movie sessions and their feasibility. These sessions are advantageous for the following main reasons: a) the popularity of motion pictures stimulates interest in the students, b) the atmosphere present in these movie sessions is one that students enjoy, which can cause them to be more comfortable in participating in discussions, and c) seeing physical concepts represented in movie scenes helps students to understand how these concepts apply to real-life situations. The fact that the students involved in this project successfully conducted these sessions for a whole term indicates that they are feasible. In terms of budget, the expenses involved in conducting these sessions will include DVD's for each conference section, popcorn and soda, so they will not be difficult to manage economically. If given a chance, these movie sessions have the ability to make great advances in the quality of the curriculum in PH 1110.

The other possible change that has stood out as having great potential as well as being easy to implement is instruction via Physlets. In my research of Physlets I have determined that these are an effective way of visually demonstrating Physics concepts and stimulating intuition in these concepts. I have learned that certain methods of presenting Physlets are more effective than others (as shown in the study comparing the Inquiry and Worked Example protocols). Physlets that are presented with predetermined parameters appear effective in improving students' understanding of the concepts involved than those that allow the students to input the parameters. Regardless, Physlets are a useful tool that could be easily implemented in PH 1110. The conferences, which generally consist of an instructor reviewing the concepts from the most recent lecture and then answering questions, could instead take place in computer labs. In this case, the conference instructor could review the concepts covered in lecture by instructing the students to use Physlets that involve the same concepts. If a student had not understand the concepts in the most recent lecture, this way he or she would now see the concept in animation instead of just seeing it on a blackboard again. Obviously it is not a guarantee that the Physlet will cause the student understand the material better. However, the ability to receive the same information in two different perspectives will not hurt. Professors will also have the ability to program their own Physlets if they had some basic knowledge of Javascript, though this unfortunately is not a process that I have been able to cover in this project. Regardless, such knowledge is not necessary. A wide variety of Physlets have been made and are available for free download. Virtually every general PH 1110 topic is can be seen on a free Physlet. There are no economic repercussions of such an implementation. It must be admitted that when a student attends the This is another possible change in the curriculum of PH 1110 that has great potential if the faculty is willing to accept it.

Multiple sources in my research have discussed the fact that although more technology that can be utilized in education may be available, it will not be beneficial if an instructor is either not well-versed in the technology or unwilling to put in the time to incorporate it in his or her curriculum. The issue is that once a professor begins in the field, they become accustomed to specific methods of teaching and stick to them. When new methods are proposed, a professor may have anxiety of a change in their program possibly being detrimental. This is an issue affecting the advancement of education that is present universally, not only at WPI.

The PH 1110 curriculum has remained the same for many years. I have learned through my interviews that because of this, the faculty teaching this course are hesitant in regards to dramatic changes in how the course is set up. My response to this is that they should simply consider the question of which is more important: adhering to what has been done so that things run smoothly, or finding a way to accomplish more as educators and improve students' understanding as well at appreciation for the field of physics. Note that these statements do not by any means imply that the current way in which introductory physics is taught is not of high quality, as it is taught by brilliant minds in a good schedule for the 7-weeks in which it takes place. However, an improvement in such a curriculum can lead to students who understand physics better, and in the long run better engineers.

Unfortunately, it cannot be denied that there is no proof that the changes in the curriculum proposed by the Visual Physics Advancement Project would be beneficial. However, there is no proof that these changes will be detrimental. In my research, I have found information that serves as evidence that changes such as Physlets or movie sessions could be beneficial, while none of the information found has suggested that these changes will be detrimental. It is my believe that although there is a possibility that the effectiveness of the teaching in PH 1110 could stay the same with the changes set forth in this project, the potential of great improvement is worth the attempt.

6. Recommendation and Future Work

I feel that the Visual Physics Advancement Project has been productive and has made great accomplishments, and I also feel that what we accomplished has paved the way for possible future projects. Probably the main thing that I feel there's a lot of opportunity to continue work is with Physlets. I feel that a lot of work can be done in regards to the possible implementation of Physlets and whoever did it would probably find it very interesting.

In my discover of Physlets as very useful teaching aids, I began to realize that they were something on which a lot of work could be done. I feel that it is possible for someone to even make and IQP out of Physlets. Someone could basically do the same thing the VPAP did with the movie sessions, only with Physlets. If someone in the future had the desire to work with a PH 1110 conference and examine the usefulness as well as the students' reactions, I personally would be interested to find out the results, and I believe it would be an interesting experience for whoever had interest in doing it.

Other work that could be done regarding Physlets is creating them. I support Physlets as something to be utilized even with just the availably ones that can be download, and it would be even better if something like a training course for programming them were created. If someone, as part of an IQP, was willing to teach professors the javascript necessary to make their own Physlets, there could be a decent response from the faculty, and once these professors have been train I'm sure they would have the desire to use their new knowledge and therefore might make it part of their teaching. Although Physlets are just a portion of my work on the VPAP, they are what first come to mind in as what I would be particularly interested to find out they are being continued.

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