Abstract

Slykhuis, David A. The Efficacy of World Wide Web-Mediated Microcomputer-Based Laboratory Activities in the High School Physics Classroom. (Under the direction of Dr. John C. Park)

This research project examined the efficacy of an online microcomputer-based laboratory based (MBL) physics unit. One hundred and fifty physics students from five high schools in North Carolina were divided into online and classroom groups. The classroom group completed the MBL unit in small groups with assistance from their teachers. The online groups completed the MBL unit in small groups using a website designed for this project for guidance. Pre- and post-unit content specific tests and surveys were given. Statistical analysis of the content tests showed significant development of conceptual understanding by the online group over the course of the unit. There was not a significant difference between the classroom and online group with relation to the amount of conceptual understanding developed. Correlations with post-test achievement showed that pre-test scores and math background were the most significant correlates with success. Computer related variables, such as computer comfort and online access, were only mildly correlated with the online group. Students' views about the nature of physics were not well developed prior to the unit and did not significantly change over the course of the unit. Examination of the students' physics conceptions after instruction revealed common alternative conceptions such as confusing position and velocity variables and incorrect interpretations of graphical features such as slope.

The Efficacy of World Wide Web-Mediated Microcomputer-Based Laboratory Activities in the High School Physics Classroom

By

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Dedication

This dissertation is dedicated to the wonderful women of my life. My wife Julie, and my two daughters, Hollyn and Lillie Jo. I thank them for the patience, understanding, and sacrifice they have exhibited in support of me.

Biography

David was born in Iowa and raised there in a small Dutch community. He attended the University of Northern Iowa as an undergraduate where his career path was influenced by Dr. Roy Unruh and Dr. Amy Phelps. At UNI, he completed a BA with an All-Science Teaching major and a Coaching minor. While at UNI, David married his high school sweetheart, Julie.

From UNI, David spent five wonderful years in Pana, Illinois. There he taught high school physical science, biology, chemistry, advanced chemistry, and physics. He also served in a variety of extra curricular activities including girls golf coach, freshman boys basketball coach, academic bowl sponsor, science fair, and class sponsor.

While in Illinois, David began attending Eastern Illinois University during the summers. After three years, David received his Master of Science in Education with an Emphasis in Physical Science from EIU. This degree allowed him to teach night classes in chemistry for Lakeland Community College. While living in Pana, David's first daughter, Hollyn, was born.

David and his family then moved to Raleigh so David could pursue a PhD in Science Education at NC State University. While at NC State under the tutelage of Dr. John C. Park, David has been a research assistant for MentorNet and a science visualization research project sponsored by GSK. While living in Raleigh, David's second daughter, Lillie Jo, was born.

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Chapter 1

Introduction

Problem

The nation is suffering from a teacher shortage. This generalized statement is only partly true. The nation is suffering from a shortage of teachers only in certain content areas and/or only in certain parts of the nation. For example, according to the North Carolina Education Research Council, North Carolina needs about 11,600 new teachers annually. North Carolina's teacher education programs only provide 3,600 new graduates each year. North Carolina is forced to make up the deficit, about 8,000 teachers, through lateral entry programs and hiring out-of-state teachers, or teachers returning to the profession (*Teacher Demand, Supply, and Quality: An Analytical Approach*). In an effort to combat this problem, North Carolina has invested more than $14 million that has helped to raise enrollment in teacher education programs by more than 14% (*Recruiting Teachers for Hard-to-Staff Schools Solutions for the Southeast & the Nation*, 2002).

Other tactics have attempted to close the bridge between teacher supply and demand by raising teacher salaries and improving their benefits. According to research by the American Federation of Teachers as reported on their web-site (<u>Survey and Analysis of Teacher Salary Trends 2001</u>, 2001), teacher salaries increased more than 4% in 2001 for the second straight year. The increase was especially high, 4.4%, for new teachers as schools tried to compete with business for college graduates. Unfortunately, the average college graduate could expect a salary offer of about $43,000, while a new teacher could only expect a salary offer of about $29,000. This represents a gain of 7.1% for business from the prior year.

Members of industry, businessmen and women, and military personal have all been recruited, especially during down economic times, into trying the teaching profession. Teach for America is probably the largest and most visible of these alternative training programs. Teach for America takes college graduates and after a single summer session places them in high need classrooms (Tell, 2001).

While these methods have been partially successful, they have not succeeded in solving the problem. Physics is one of the areas where there has traditionally been one of the largest shortages of qualified teachers. In a survey of schools in 1993-94 by the US Department of Education, 18.4% of schools with a vacancy in physical science found the position difficult or impossible to fill (Henke, Choy, Geis, & Broughman, 1996).

One method used by school districts to combat the lack of physics teachers is by putting an under qualified teacher in the classroom. This teacher is typically from either mathematics or another content area of science and is asked to teach physics. According to Ingersoll (2001) over half of all secondary students enrolled in any given physical science class are being taught by a teacher who does not have the equivalent of at least a college minor in the subject. His analysis of US Department of Education statistics also showed that teachers who are most likely to be teaching out of their area are new teachers in small schools. This can result in a didactic style of instruction. A teacher is this situation is concerned about learning the content themselves and does not have the training necessary to be comfortable using hands-on or inquiry-based teaching methods. This is not the fault of the teacher. They have not been given the pedagogy for teaching this subject and are therefore disadvantaged before they even begin.

Resource

Over the course of the last 10-15 years, the Internet has exploded into society and become nearly ubiquitous. Applications for the Internet have run the gamut from over-hyped under-producing commercial ventures to simple postings about one's own family. Nearly every sector of the economy now incorporates some application of the Internet. Education is not an exception. It is used as a content resource and a means of collaboration among teachers and students.

Within the last few years instead of using the Internet in the classroom, the Internet has begun to become the classroom itself. Many universities have been putting classes online to allow for students to access them wherever, and to some extent, whenever they want to. There has been a great deal of research concerning how students in these classes perform and the pedagogy necessary to teach them. For example, in a study by Yazon, Mayer-Smith, and Redfield (2002) over 500 undergraduates used the web to replace the traditional lecture section portion of an undergraduate genetics course. Eighty-five percent of these students felt that the web-based course was more interactive than the traditional lecture class and gave them greater control of their own learning. Sixty-seven percent of these students felt that the web-based course promoted greater understanding than rote learning.

Students facing the demands of needing continuing education for employment, living far from a university, or being unable to afford to attend school full time often turn to distance education as an alternative (Lemckert & Florance, 2002). Lemckert and Florance (2002) suggest that in their field, engineering, real-time web-mediated laboratory experiments serve as the next best thing to the students being in the laboratory itself. In this case, the students use their web-browser to manipulate an experiment that is being carried out in a laboratory and observed through the use of web-cam.

Theoretical Framework

The basis for this study was rooted in constructivism. Constructivism is simply the belief that students learn by constructing their own knowledge. They are presented with something that contradicts their prior knowledge and in their current social setting they form new ideas or knowledge. Constructivism is widely believed to be rooted in the works of Piaget, Dewey and Vygotsky (Dalgarno, 2001; Ramos, 1999; Terwel, 1999).

Several educational policy initiatives have been created in the past few years in an attempt to bring the United States educational system up to par with the rest of the world. These include the Goals 2000 Act and the recent No Child Left Behind legislation. Two things are common in the recommendations and mandates of these programs. First, there is a call for greater constructivism in the classroom. Teachers are urged to stop treating students as receptacles of knowledge for them to fill by didactic teaching methods and to instead help them to learn how to discover concepts independently. Second, there is a push to bring technology into every classroom. This technology can aid teachers in their delivery of material and with an Internet connection can open up the entire world as their classroom. Together, these two things, constructivism and technology, are where the hopes and dollars of the educational system are currently being placed (Lunenburg, 1998).

Unfortunately there is often a wide gap between what these programs call for in terms of constructivist practice and what is actually taking place in the classroom. In the Netherlands, the Dutch National Curriculum is based on constructivist ideas but the practice of Dutch teachers is observed to be far from constructivist (Terwel, 1999). Teachers in the US profess that they would like to be teaching with constructivist methods but cite such issues as time, availability of resources, administration pressure, and classroom management for reasons as to why they still teach in a traditional manner (Ramos, 1999).

Constructivism is not without detractors. Some feel that constructivist principles in the classroom have only been shown to succeed in ideal situations and do not work in the 'real' world. There is also a feeling that no education system should rely entirely on one philosophical viewpoint. This would inherently prevent some students from being provided their best opportunity to learn (Terwel, 1999). Therefore to best reach each student, this study was grounded in constructivism but is not necessarily limited to that viewpoint.

Constructivism and the Internet are especially well suited for each other. In constructivism, students are to assemble the concepts themselves. This is especially compatible to web-based activities that utilize hypertext and hypermedia as well as computer simulations. In all of these activities the student is in charge of directing the program to either run the simulation with their set parameters or to launch certain text materials or media. Constructivism supports the idea that the learner is at least partially in control of the sequence and selection of content. In many web-based tutorials the student can choose to delve into any one area as much as they choose. This power rests with them. Constructivism suggests that students need to be assisted with their own metacognition. This can be achieved with the use of concept maps that can be made so easily on the computer (Dalgarno, 2001). This often aids students in allowing them to link concepts as they see them in their mind. Lastly, constructivism states that learning is a social interaction. This can easily be achieved in an online environment through the use of asynchronous discussion tools such as email or message boards, or synchronous discussion such as chat rooms, and instant messaging.

Constructivist theory contends that the optimal learning environment for students allows them to actually manipulate the material for themselves, both tactilely and conceptually, and create their own knowledge. This theory is widely regarded throughout science education as the best method to teach science. Students need to be able to experience certain phenomena and relationships themselves (Lord, 1998). This will allow them to form deeper and more permanent understanding of the science concepts. For example, a study by Lord (1999) compared two groups of college students taking an environmental science course. The first group consisted of two classes who received traditional teacher-centered lecture-based curriculum. The second group consisted of two classes that received constructivist-based curriculum. In these classes the students worked in small groups on critical thinking problems and interacted with the instructors in a discussion format. The second group significantly out performed the first group on exams and rated the course more favorably.

Unfortunately, many science teachers are not using this model. This may be due to that fact that constructivist teaching is not always intuitive. It may be easier for teachers to revert to teaching methods, such as lecture, which they are familiar with from their own successfully completed schooling. Constructivism requires a teacher be willing to become a facilitator of knowledge rather than a transmitter of knowledge. A teacher must be prepared to allow the students to work in groups and help to provide the means necessary for that student to formulate their own truth about the topic (Hand & Vance, 1995). I contend that the likelihood of a teacher to abandon constructivist philosophy will increase when teachers are teaching outside of their comfort area. Therefore, while schools will put a variety of people in the classroom to teach physics, it may not be taught in what is generally thought to be the best possible method.

Research Questions

Given the shortage of physics teachers and the availability of the Internet, one solution to provide qualified physics instruction at the high school level is to develop and design a hands-on online physics course for high school students based on the national science standards and delivered in a constructivist fashion. Such a course would allow school systems to put a teacher or adult facilitator in the room as the teacher of record because the content and pedagogy would be handled online. The classroom supervisor would need only to manage the classroom and be a technical advisor and materials provider.

The essential question is; can a hands-on online physics unit be developed for high school physics students that is comparable to a hands-on physics unit taught by qualified physics teachers?

As a part of this study, three additional questions were answered. First, were there factors that were not physics related such as computer skill or familiarity with computers that were predictors of success in the online physics unit? Second, what were students' attitudes and views about physics during the computer-based physics unit, and did these views change?   What level of conceptual understanding of physics did these students possess, and was there evidence of any conceptual change?

Limitations

The sample of students that was chosen for this project was not chosen randomly. Instead they were chosen because when contacted, their teachers agreed to volunteer for this project. These students came from diverse backgrounds including three counties in North Carolina that are not near each other geographically and quite different in terms of their demographics. The population of physics students in North Carolina is a relatively small and homogenous group, as all the students have to meet certain prerequisites, such as algebra II, to take physics.

While the long-term goal for this research project is to determine if a hands-on online physics course could be appropriate for schools without qualified physics teachers, it was not tested in schools without qualified physics teachers. The classes that completed the online unit did so during their physics classes. Their physics teachers were asked to reduce their role as an instructor and be available only for technical assistance and classroom management during the unit.

The teachers who taught the unit in their classrooms in a more traditional manner were given lesson plans for completing the same material as the online group. There was variation among these teachers as to exactly how they completed these lesson plans. They brought their own individual styles and interpretations to the lessons. The lessons were reviewed in person with the teachers prior to the beginning of the unit in an effort to control this variation.

While there were certainly limitations to the study, this was a special situation that merited this research. The ability to do hands-on online classroom work has been studied very little, if at all. Also, the population of physics students is very homogenous thereby reducing the impact of the participants being non-randomly selected. In fact, in the last five years only between 3.4-4.2% of high school students in North Carolina have enrolled in a physics class (*The North Carolina Statistical Profile*, 2003). Lastly, this research project examined the impact of a hands-on online physics unit from several perspectives. Not only was the knowledge gain compared in a traditional manner, but the students' demographics were examined to determine predisposition to success, their views and attitudes about physics were examined, and their understanding and change in conceptual knowledge of specific physics concepts related to the unit were examined. The summation of all of these different views provided the most accurate assessment of the efficacy of hands-on online high school physics instruction.

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Chapter 2

Literature Review

Introduction

This dissertation research project examined how effective a new technology can be at delivering physics curriculum to the high school classroom within the framework of constructivist philosophies. This is certainly not the first time that new technology and philosophy have been wedded to herald improvement and change. Educational history is ripe with examples of new technology and the 'progress' that they can bring to the classroom. This literature review will examine these technologies and the philosophies in which they were framed.

> How can new technologies best be integrated with existing institutions of instruction? Most change is evolutionary rather than revolutionary, and technology-based approaches to instruction seem no different, despite the immense changes they may ultimately engender (Fletcher, 2003, p.96).

Usually when people speak of the changes that are being brought about in education by technology, they speak of the 'technological revolution'. This is true whether they are talking about the introduction of the personal computer or the growth of the Internet and World Wide Web. This is also true if one looks further back in the annals of American education at the advent of the film projector, radio and TV. Because each of these technologies, as well as others, entailed its own mini-revolution, it is perhaps better to look at the development of technology in the classroom from an evolutionary lens. Looking back and investigating how technology, educational philosophy, and classroom practice has changed will perhaps provide the best glimpse into the future of how technology, educational philosophy, and classroom practice will continue to evolve.

One hopes that the best current educational philosophy is what drives the technology that is used in the classroom and not vice versa. With that in mind, it will be most useful to begin this perusal of history with how the prevalent educational philosophy has shifted through the years. This paper will arbitrarily use 1920 as a beginning point to examine the evolution of technology and its uses in the American classroom.

1920's-1950's Educational Philosophy- Progressivism

> Progressivism- An educational theory that emphasizes that ideas should be tested by experimentation and that learning is rooted in answering questions developed by the learner. Progressivism was a contemporary American educational theory. From its establishment in the mid-1920's through the mid-1950's, progressivism was the most influential educational view in America (Corey, 2003, p.2).

The progressive movement that became the dominate educational philosophy of the 1920's and beyond was born at least partially out of the work of John Dewey. This new movement was an extension of the pragmatist viewpoint and also a direct reaction against formal authoritarian schooling (Gutek, 1997). A progressive school at this time was one that followed a child-centered instead of subject-centered curriculum. It was interested in trying to meet the needs of the whole child. The children at a progressive school were to play a central role in determining the content of their education (Zilversmit, 1993).

Around 1900, John Dewy moved to Chicago and established his own school. This was the first laboratory school with the express purpose of studying teaching and learning. His attempts to scientifically study the best methods for teaching and learning guided his belief that educational reform was necessary. He conceived that students needed to be the center of the classroom working on problems and not listening to authoritarian teachers (Cremin, 1961; Zilversmit, 1993).

In the era following WWI, the educational system grew and consolidated throughout the country. Enrollments in schools nearly doubled, while the number of school districts declined as the one room schoolhouse gave way to increasingly larger school systems. The notion of schooling was further centralized through the increasing efforts of the United States Office of Education as well as by a tenfold increase in national organizations such as the National Educators Association (Cremin, 1961). All of these national influences and transformations in the school system left the system ready for change and that change appeared in the form of progressivism.

The founding of the Progressive Education Association in 1919 signified that this movement had truly arrived and was now at the forefront of American education. The first act of this group was to devise a statement of seven principles. They were as follows (Cremin, 1961):

1. Freedom to develop naturally
2. Interest the motive of all work
3. The teacher as a guide, not a task-master
4. Scientific study of pupil development

5. Greater attention to all that affects the child's physical development
6. Co-operation between school and home to meet the needs of the child-life
7. The progressive school a leader in educational movements.

While Dewey is largely responsible for many of the beliefs held by progressivists in education, he often did not agree with the cause that the organizations were pursuing. Often he believed progressivists were simply anti-establishment and anti-school and had little in mind for how to effectively reform the schools (Gutek, 1997).

Despite the best efforts of the progressivists to enact school reform, Cuban (1984) estimates that between 1920 and 1940 fewer than one-fourth of any of the classrooms in a given district were using progressivism principles. Even in school districts where progressivism was widely encouraged by administrations, such as in New York and Denver, he estimates that no more than half of the classrooms were truly progressive. Cuban points out the fact that most of the progressivism that was in practice was in a hybrid form where teachers mixed bits and pieces of the progressivism ideals with their traditional practices.

1950's-1980's Educational Philosophy- Behaviorism

Behaviorism- A psychological theory that asserts that behavior represents the essence of a person. Behaviorists contend that all behavior can be explained as response to stimuli. Arthur W. Combs contends, "We are what we are and what we do what we do, not because of any mysterious power of human volition, but because outside forces over which we lack any semblance of control have us caught in an inflexible web. Whatever else we may be, we are not the captains of our fate or the masters of our soul." John B. Watson (1878-1958) was the principal originator of behaviorist psychology and B. F. Skinner (1904-1990) its best known promoter (Corey, 2003, p.2).

Despite excellent intentions, progressivism manifested itself poorly in the schools and was falling out of favor as the prevalent educational philosophy in the 1950's. B. F. Skinner was ready to fill in the void with his brand of behaviorism. His impact on educational philosophy can hardly be understated. During the writing of one of his last pieces on education, he said " During the past 30 years, for example, I have published 25 papers or chapters in books on education" (Skinner, 1989, p.85).

Behaviorism, or at least Skinner's brand of it, was built on the works of John B. Watson as well as Ivan Pavlov (Nye, 1992). Skinner's fundamental premise is that organisms, including humans, have certain behaviors and these behaviors have certain consequences determined by the physical and social environment. Depending on the consequence, the organisms will be more or less likely to repeat the behavior (Nye, 1992).

As nearly everyone who has taken an educational psychology class can attest, Skinner's theories use positive reinforcement, negative reinforcement, and punishment. As schools have changed and issues of the behavior of students arose, these ideas gained widespread popularity for controlling students' actions. If a teacher sees a behavior they want to encourage they can give a positive consequence or reward. This is positive reinforcement. Behaviors can also be encouraged through the use of negative reinforcement, which will remove an adverse consequence if the proper behavior is followed. Punishment, on the other hand, is used to discourage any behavior. The probability of a behavior being repeated can be reduced either by adding an adverse consequence or removing a favorable consequence (Nye, 1992).

His impact on teaching was not limited to behavior management. He also forwarded a method of teaching that called for daily measurement of student performance, the graphing of these results, and analysis of behavior (Hawkins, 1990). He also championed programmed learning either through the use of teaching machines, which will be visited in greater detail later in this paper, or books such as *The Analysis of Behavior* (Holland & Skinner, 1961) that a student would complete as a self-guided type of workbook.

Skinner and his behaviorism has not been without its critics. One of the main criticisms of his work is that he essentially ignores any physiological or mental processes in determining how someone will behave. His concern is only with the outward manifestations of behavior and consequences (Simon, 1988). Another major criticism of Skinner is his willingness to apply his conditioning of rats and pigeons so freely to people with little regard for the human ability of free choice (Moravcsik, 1988; Nelson, 1988).

Skinner (1989) himself did not resign on the issue of education, writing about what he perceived as the school of the future as late as 1989 (he died in 1990). His vision of this school of the future was one where a student would want to come to school and was able to choose subjects and topics to their own liking. They could then follow a set of programmed instruction on this topic. Teachers will become more like counselors and stay in contact with students for several years. Through the use of his programmed instruction "…we can teach twice as much as is now taught in the classroom in the same time and with the same effort" (p. 96).

1980's –Today Educational Philosophy- Constructivism

> Constructivism- An educational theory that emphasizes hands-on, activity-based teaching and learning during which students develop their own frames of thought. Piaget concludes, "It is assumed that learners have to construct their own knowledge, individually and collectively. Each learner has a toolkit of conceptions and skills with which he or she must construct knowledge to solve problems presented by the environment. The role of the community, other learners and teacher, is to provide the setting, pose the challenges, and offer the support that will encourage construction" (Corey, 2003, p.1)

The underlying assumption of constructivism is self-evident in the name itself; the learner constructs knowledge. This typically takes the form of new information being internalized and processed through the learner's previous ideas and experiences (Crowther, 1997). This will often manifest itself in the classroom through teaching practices that use cooperative grouping, hands-on and heads-on methods, using input for students and being student-centered (Crowther, 1997). Because of their hands-on nature, the subject areas of math and science were quickest to acquire this philosophy, incorporate it into their pedagogy, and research its effectiveness (Vanderstraeten & Biesta, 1998).

Besides Piaget, many of the ideas of constructivism are attributed to Lev Semenovich Vygotsky. Vygotsky (1997) said, "in education it is much far more important to teach the child how to think than to communicate various bits of knowledge to him" (p. 175). One of Vygotsky's tenets is that learning would be most meaningful to students if they were given the opportunity to construct knowledge and discover new ideas for themselves (Wink & Putney, 2002). While both Piaget and Vygotsky are often mentioned together in discussions of constructivism, they did have some philosophical differences as well. Piaget believed that learning followed development and Vygotsky believed that development followed learning (Wink & Putney, 2002).

The social context of learning is vital to a constructivist. The mind is not an isolated storage facility for facts. Instead, meaning making is accomplished within a context of peers, relationships, and the environment (Garrison, 1998). This typically will manifest itself, for the constructivist, as the need for learners to work in group settings. In these settings, individuals will be co-constructing knowledge. They need not always reach consensus as long as they are able to help each other construct, or reconstruct as necessary, the new knowledge (Pepin, 1998).

Many pre-service teaching programs are now preparing beginning practitioners to teach from a constructivist perspective. Gagnon and Collay (2001) outline six basic principles that should accompany any constructivist learning design. First, the situation of the class frames the goals and agenda for that class.

Second, groupings are made so that the social structures and group interactions will foster learning. Thirdly, and perhaps most importantly, bridges are built between students' past knowledge and new knowledge. Next, prompting questions are posed to the students to continue and extend the investigation. Then students are asked to exhibit and share with their peers what they have learned. Lastly, the students and the teacher reflect on the collective learning experience. While many new teachers may be learning how to follow these practices, Marlowe and Page (1998) caution that new teachers may experience stiff resistance to these ideas from veteran teachers. In their book, *Creating and Sustaining the Constructivist Classroom*, they offer practical suggestions for successfully implementing constructivist ideals despite this resistance.

Technology and Progressivism- 1920's – 1950's

> A few years ago, while researching how teachers taught in the 1920's, I came across a 1927 National Archives photograph of a Los Angeles teacher in the midst of a geography lesson in the cabin of an airplane. Here was an aerial classroom of students viewing urban geography firsthand; this was to demonstrate clearly how progressive education had influenced the city's teacher corps (Cuban, 1986, p.1).

While progressivists were trying to change the landscape of traditional classrooms, and the above quote shows an extreme example, most of the technology of this era did not necessarily move the students out of their desks. The primary rise in technology during this time was the increase in visual aides, including the educational film. Thomas Edison is quoted as saying (Cuban, 1986, p.9) "I should say that on the average we get about two percent of efficiency out of schoolbooks…The future of education, as I see it, will be conducted through the medium of the motion picture …where it will be possible to obtain one hundred percent efficiency." Thomas Edison further proclaimed (Saettler, 1990, p. 98) "Books will soon be obsolete in the schools. …It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed in ten years."

While Edison's view of the future school may not have been accurate, similar sounding rhetoric has been heard with the advent of nearly every new technology. That is not to say that the film did not influence American education. During this time educators were interested in supplementing their classrooms with visual aids. To illustrate the importance visual instruction was being given between 1919 and 1923, five national organizations of visual instruction were formed during this four year period (Saettler, 1990).

Visual instruction was to take many forms, as motion pictures, both silent and with sound, to many varieties of still projection such as the filmstrip, slides, and eventually overhead projectors. Teachers desired at this time to be able to show students exactly what they were learning. Though films, both silent and sound, garner many of the headlines through this time period, forms of still projection were low cost alternatives that were sought by many schools. Because of the non-threatening nature and ease of use of this technology, the value of still pictures and graphs were embraced by many types of teachers (Finn, Perrin, & Campion, 1962).

It was estimated that by 1962 there were 200,000 pieces of still projection equipment in schools throughout the United States. While that may seem to be a sizeable amount, these were to service over 100,000 schools and 36 million students (Finn et al., 1962).

The sound film, or 16mm sound motion picture, was the technology most adored and promoted by progressivists during this time period. This was a technology that could engage students and transport their mind's eye out of the classroom to stimulate thinking and learning. During this time, research was conducted with control groups (no films) and experimental groups (with films) that showed the classes with films achieving the same or higher test scores and greater motivation (Cuban, 1984).

While highly touted, one of the biggest obstacles to 16mm sound films actually being used in schools was the ability to purchase and maintain the equipment. The number of projectors in the schools went from well less than 1 per 100 teachers at the beginning of this time period to about 5 per 100 teachers by 1950. By 1960, this number had only increased to almost 10 per 100 teachers (Finn et al., 1962). Another barrier to the widespread use of the 16mm sound film was the production and distribution of quality educational films. Numerous companies went into the business of educational films with mostly poor returns on their investments. By the end of the 1940's most film production had been centralized either to textbook companies or universities (Saettler, 1990).

This time period also endured two significant events that affected the use and availability of films and equipment; the Great Depression and WWII. The Great

Depression was responsible for the merger and folding of many of the film making companies as well as projection manufacturers. Despite the effects of the depression, visual instruction continued to grow, as measured by the number of units purchased in schools, albeit very slowly (Reiser, 2001b). During WWII, American armed forces made extensive use of the film as a training tool. It was estimated that the Air Force alone produced over 400 films and 600 filmstrips in just two years. It was projected that the military showed over 4 million films or filmstrips as part of its intensive training programs (Reiser, 2001b). This extensive use of films by the military monopolized the market and made it difficult for schools to purchase equipment during this time (Finn et al., 1962).

Survey data compiled by the National Education Association is reported in Cuban (1986) and indicates that in 1946, 69.6% of elementary teachers and 49.9% of high school teachers frequently or occasionally used films in class. In 1954, the survey was repeated and 75% of elementary teachers and 56% of high school teachers reported frequent or occasional use of films. In his search of the then current literature for explanations for why these numbers weren't higher, Cuban found the following four reasons as the primary obstacles to the use of film in the classroom (p.18):

- Teachers' lack of skills in using equipment and film
- Cost of films, equipment, and upkeep
- Inaccessibility of equipment when it is needed
- Finding and fitting the right film to the class

During this time period there was another technology that was growing besides film; educational radio. Educational radio began in the 1920's and 1930's but there was not a steep increase in the number of radios in the classroom until after WWII when radios became inexpensive and mass produced (Finn et al., 1962). Educational radio programming first began on commercial stations and then moved largely to universities and their Schools of the Air (Cuban, 1986; Saettler, 1990).

In 1935 and 1936, the U.S. Office of Education ran a very successful Radio Education Project, however, funding for the project was cut by Congress in 1940 (Saettler, 1990). Throughout this time it was very difficult to assess the number of schools or students that were regularly using educational radio. Depending on the survey and its methods, estimates for educational radio usage could vary by 500,000 to 1 million students when describing the same area. Clearly though, educational radio never had the revolutionary effect that some dreamed it could. By the 1950's educational radio was already being phased out and the transition away from radio was accelerated by the advent of the television (Cuban, 1986).

Technology and Behaviorism- 1950's – 1980's

As radio was passed over as the next great technology, television appeared ready to take its place. After WWII and into the 1950's, the spread of televisions was dramatic across this country. The Federal Communications Commission (FCC) at this time was unsure of how to handle the idea of educational television. In 1949, when the FCC appropriated more than 2,000 new stations, none of them were reserved for educational use. A few leaders, however, were quick to point this out and in 1952 the FCC reserved 242 television stations for educational use (Reiser, 2001b; Saettler, 1990). Educators promptly seized this opportunity and by 1955, there were 17 educational stations across the country, and by 1960 there were more than 50 stations (Reiser, 2001b).

Television was also the first major technology to receive heavy doses of funding that were not part of a normal school budget. It is estimated that the Ford Foundation spent in excess of $170 million on educational television between 1950 and 1970 (Reiser, 2001b). Federal funding was also available for educational television including $32 million appropriated by the Communications Act of 1962.

It is important to note a distinction that became inevitable as the medium of television grew; the difference between educational television and instructional television. Educational television is programming that has broad ideals that may be to teach or to enlighten the viewer. Instructional television is designed to specifically teach or relate concepts of a specific subject matter as part of a course of study (Saettler, 1990). Educational television would eventually evolve into public television and was formally established in 1967 with the Public Broadcasting Act.

Instructional television was hailed as the next great revolution in schools because it would have the ability to bring any subject to any student. It was also intended to save a school district money and help solve an ever-increasing teacher shortage (Saettler, 1990). Instructional television, however, did not follow that path. With educational television becoming more popularized it became increasingly difficult to obtain quality instructional television programming. Most often television was used in the classroom only as a supplement to regular instruction or as a teaching aid. Only in American Samoa did instructional television provide the content of the school system (Cuban, 1986).

The most extensive study of the use of instructional television was done by Dirr and Pedone in 1976-1977 and was reported by both Cuban (1986) and Saettler (1990). This study found that 72% of teachers had instructional programming available to them. Of this set only 46% watched at least one series regularly. Only one-third of the respondents indicated that they had viewed at least one instructional television program in the last four weeks. The amount of television viewed varied from about 60 minutes per week in the elementary classroom, to about 45 minutes a week in the junior high classroom.

While television once again failed to create the revolution that its supporters had hoped for, there was another technology emerging simultaneously that was directly tied to the current prevalent behaviorist theory. This was the teaching machine. Fry (1959) espouses the virtues of the teaching machine in this "…headlong technological age" (p. 28). According to Fry, teaching machines will be able to remove the "teacher variable" (p. 31) from classroom studies, act as tutors for gifted children, provide additional course offerings for small schools, and raise minimal curriculum standards for a district or a state. Once again, a new technology was being heralded as a revolution of the classroom.

As with most of behaviorism, B. F. Skinner was at the forefront of the push for teaching machines and programmed learning. A minimal teaching machine is one that requires the student to compose the correct answer, not select it from a list.

This machine must be able to lead a student through a series of small sequential steps (Skinner, 1968). Such a machine was a direct application of behaviorism because each time a student's answer matched the revealed correct answer it provided positive reinforcement and increased the likelihood that this behavior would be repeated (Reiser, 2001a).

Skinner's requirements for what a teaching machine must consist of usually manifested itself in some sort of mechanical device. This device would only reveal a small amount of text at a time, usually in the form of a fill in the blank statement. The student was then required to write his/her answer in the designated space. If the answer was correct, the statement was typically notched or punched by the machine so it would not be revisited during the session. Depending on the sophistication of the machine, information about why an answer was right or wrong may also be revealed. The machine then moves to the next statement or question in the sequence of instruction (Day, 1959). The teaching machines varied in price from simple $50 models to sophisticated models that could incorporate film for approximately $5000. Typical machines fell somewhere in the $200-$1000 range ("How Machines Do Teaching Job," 1960).

The interest in and use of teaching machines and programmed instruction enjoyed a peculiarly rapid rise and decline. In an annotated bibliography, Willerding (1961) published over 100 references to teaching machines, their use, and their theoretical underpinnings, almost all of which appeared after 1958. By the late 1960's, however, programmed instruction and teaching machines were promptly on the decline. By the early 1970's most publishers and manufacturers were out of the business of producing teaching machines and programmed materials (Saettler, 1990).

Technology and Constructivism- 1980's – Today

> Information-processing technologies and constructivism, separately and often together, have remade substantially our conception of the challenges of learning. Apart from the practical applications to education, information-processing technologies have spawned the computer metaphor of the mind as an information processor. (Perkins, 1992)

This period in education was dominated, and continues to be dominated, by a single technology; the computer. Since 1951 and the development of the first commercial computer, UNIVAC I, the inclination has been for computers to become smaller, more reliable, faster, and less expensive (Saettler, 1990). There have been other new technologies introduced and used in teaching, such as the VCR. Its primary role, however, was to replace the film projector as a method of showing instructional movies and added relatively little in the way of new instructional techniques. While an early computer could be seen simply as an extension of a teaching machine, it quickly became obvious that computers had much more to offer the classroom.

The evolution of computers in the classroom was one of the fastest changes in education. The first Apple microcomputer was introduced in 1977 and the first IBM microcomputer in 1981. By 1985, it was estimated that there were already over 1 million computers in American schools. By 1988, this estimate had reached 3 million (Saettler, 1990). By the year 2000, 84% of teachers reported that they had computers available in their classrooms (Baule, 2001). Cuban (1986) notes, "As with film, radio, and instructional television, predictions of computers reshaping how school will be organized, how teachers will teach, and how students will learn surface repeatedly" (p. 73).

By the mid-1980's simple drill and practice or remediation dominated the use of computers in the classroom (Saettler, 1990). As the computer advanced and developed, drill and practice software evolved first into tutorial software, and then simulation software, and finally problem solving software. The computer was also used as a tool in education by both students and teachers with the development of word-processing, database, spreadsheet, and graphics applications (Bozeman, 1999).

One of the advances that proved to be particularly effective and fitting for constructivists was the development of hypertext. Hypertext allowed the computer to have greater flexibility and non-linearity than any system prior to it. This advance allowed students to criss-cross the landscape of the learning environment in a way that allowed them to acquire the knowledge most relevant to them (Spiro, Feltovich, Jacobson, & Coulson, 1992). The ability to add hypertext and allow the user the cognitive flexibility to choose his/her own path became integrated into nearly all educational technology of the 1990's. In fact, in 1998, Petraglia writes, "Some level of hypertextualization has almost been taken for granted … one can more easily list the environments without hypertexual capabilities in some form than those that incorporate them" (p. 86).

While more and more high quality educational software was being developed and marketed, especially at the elementary level, the next evolution in education with the computer happened even faster than the spread of the computer itself. This was the rise of the Internet and the World Wide Web. The Internet was born in 1969 as a military system called APRANET. The original ARPANET started with 4 hosts (a computer with a registered IP address). By 1980 the Internet had grown to about 200 hosts, and by 1990 this had increased to over 300,000 hosts. Then, Tim Berners-Lee invented the World Wide Web and in 1991 physicist Paul Kunz demonstrated the WWW's ability to utilize the Internet. This sparked interest in the Internet and by the year 2000 there were nearly 100 million hosts (Festa, 2001; Zakon, 2003).

Jonassen, Peck and Wilson (1999) describe five attributes of meaningful learning from a constructivist viewpoint. According to them the learning should be active, constructive, cooperative, authentic, and intentional. They portend that the Internet is a wonderful source of learning activities that are tools for facilitating knowledge exploration. Through either self-directed projects or web sites with prescribed projects, Internet activities can meet all five of their criteria. Students actively seek out the information to solve a problem or answer a question. Once they find the information they have to construct their own knowledge. This work is often carried out in a cooperative group with students in their own class or even with students from across the country. The activity is authentic because the students are given real world problems which increases motivation making their actions intentional.

Constructivist uses of the computer and its related technology, whether it is from out-of-the-box software or from WWW sites, almost always follow a few of the same guiding principles as mentioned above. Further advances in computing have added the ability to incorporate simulations of increasing complexity and modeling using virtual reality. These uses have many advantages. First, students enjoy them. They also are usually of lower cost and often more safe and practical than carrying out the actual activity. The flexibility built into these programs allows the user to feel less threatened and they can actually encourage socialization and collaboration as the students work on the projects in groups (Maddux, Johnson, & Willis, 2001).

Implementing the technology of the computer, the Internet, and the World Wide Web has proven to be a difficult task. Schools and individual teachers are all situated somewhere on a continuum of technology knowledge and use. The more knowledgeable and comfortable a teacher is with the technology the more likely they are to utilize the technology to engage students in authentic project based learning and not as an electronic worksheet (Johnston & Cooley, 2001). To help implement this new technology so that it can be most effectively applied, schools need to offer on-the-job training to teachers, moral and technical support, create a consistent long-term plan for the use of technology, and realize that everyone is responsible for the transformation to a technologically savvy school. (Gooden & Carlson, 1997).

The World Wide Web and the Internet

With the continued growth and development of the WWW and the Internet, it has not only become a key feature in the classroom, in many cases it has become the classroom itself. Leading the charge in using the Internet as the classroom have been colleges and universities. One of the most visible leaders has been the University of Phoenix with its frequent ad banners on the Internet. According to their own web site (University of Phoenix, 2001) you can,

- Take classes at your convenience -- all from your computer
- Earn one of the most current and relevant degrees offered in the areas of Business, Technology, Education, and Nursing
- Complete your degree in only 2-3 years, in most cases -- faster than many traditional universities (p.1)

More traditional institutions have also joined the on-line market as Harvard, Columbia, and The Chicago School of Business, just to name a few, all offer on-line courses and degrees (Smith & Broom, 2003).

Putting courses and entire degree programs online has been the source of much debate in the academic community. Those opposing online classes argue they will lower the standards of education, and in the extreme, eventually lead to the death of the campus university. The proponents of online classes argue that by offering more courses online students will become better consumers and market forces will demand universities offer more high quality courses both online and on campus. This market force and improved quality will then combine to strengthen the campus university (Weller, 2002).

One of the significant features that separates the Internet as a means to both facilitate and lead learning is its ability to accommodate computer mediated communication (CMC). This can take many different forms that may include; email, group conferencing systems such as bulletin boards, mediated and non-mediated chat rooms or groups, and instant messaging (Santoro, 1995). Communication via the Internet is dissimilar from face-to-face communications in several ways. First, many of the subtle clues from body language and facial expressions are lost. This can result in confusion from written communications, especially in email. CMC also has the ability to be asynchronous and can offer users some degree of anonymity. Lastly, a message delivered by some form of CMC has the potential to reach a greater audience than face-to-face communications (Weller, 2002).

Using CMC in an on-line course can be very powerful when used correctly as it can impart the perception of collaboration or community. This is an important addition from a constructionist viewpoint that could otherwise be missing in an on-line course. Weller (2002) offers suggestions for how to implement CMC in an on-line course. First, the structure of the CMC needs to match the students and the course. If email is required, then all students need to have email accounts. Also, if conference postings are going to be required, the goals need to be clear for all students. Second, the instructor needs to take advantage of asynchronous communication, as the lack of time to attend class is one of the largest factors in taking an on-line course. Third, the instructor needs to be ready and willing to change. If students are clearly using one type of CMC instead of another, change the requirements so that communications are maximized. Lastly, a consistent moderating style needs to be established to structure the communications and guidelines need to be specified concerning the degree of online decorum that is expected.

Why would teachers and schools turn to computer technology to assist in instruction? One reason is students can progress at their own pace and use any amount of time necessary for them to understand the material. Because of this, it appears fewer students are left behind. Studies in the military have also shown instructional time can be reduced anywhere from 20-80%. Technology based instruction is also more cost effective than tutoring, reducing class size, or increasing instruction time. Lastly, and certainly not least, students prefer technology-based instruction (Fletcher, 2003).

The Standards

During the past 15-20 years another force has been driving education. This force is not one of educational philosophy, but of educational policy and it has left an undeniable mark upon education. This force is Standards. Technology has become such an element of the modern culture that it is perhaps more involved in the standards movement than any other area. The technology in these documents is certainly not limited to the computer and Internet, nor are they concentrated on teaching technologies. In fact, the documents make specific references to their broad definitions of technology. They do serve to illustrate, however, how far our educational system progressed from traditional 'chalk and talk' methods and how teachers are under increased pressure to learn and model technology use.

The International Technology Education Association has published two sets of standards. The first, *Standards for Technological Literacy- Content for the Study of Technology* (2000), is a document that describes what students should know about technology and its relationship to society at different grade levels. The second, *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards* (2003), describes how teachers are to assess if the content standards are being achieved. It also proposes methods for teachers to receive professional development on technology, and suggests how teachers and administrators together can create guidelines to establish a successful technology education program.

Technology and science have become intertwined to such a degree that specific references to and goals about technology have been integrated into both of the standards documents for science education. *Benchmarks for Scientific Literacy,* (1994) devotes section three to the Nature of Technology and sets benchmarks for three different aspects of technology at all grade levels. The *National Science Education Standards,* (1996) has a section relating science and technology in each of its levels of content standards.

The Role of Science Education

Science education moved swiftly to incorporate technology not only related to science and its advancements, but also as a teaching and learning tool. Shortly after the conception of the personal computer, science teachers were quick to realize their potential in the classroom. Science teachers built numerous devices that could interface with the computer, especially the Apple Computer, and were used to collect data for science experiments. This would eventually evolve into a large industry with companies of nearly all sizes offering teachers ready-made interfaces, probes, and curriculum to do real-time data collection on science experiments. Anecdotally, it seems that often the science departments are one of the most involved in new technology and its uses in a school system.

Science education has also been the discipline to quickly embrace constructivism and to heavily research its effectiveness. For example, a study by Lord (1999) used two classes of traditional lecture based environmental science compared to two classes of small group, question-discussion based environmental science. He found the students in the class with the constructivist principals performed higher on exams, rated the class higher, and were more likely to take part in out of class activities. Also, Yager and Weld (1999) reported on a project with 20 school districts in Iowa to infuse the Scope, Sequence, and Coordination approach, which relies heavily on constructivist principles, into science departments. Their results indicated students' achievement scores increased versus those in traditional textbook classes and low ability students and females were particularly aided by these methods.

Science teachers more rapidly adapted constructivist principles due to the nature of the science classroom. Even in a traditional lecture based science class there was almost always a laboratory component that required the students to work in groups. This helped science teachers to simply modify some of their pedagogy instead of needing to completely start over to gain a more constructivist perspective. That is not to say science teachers won't have to alter how they teach.

Science teachers need to be more flexible in their planning, and able to quickly react to new situations when allowing students to complete open ended projects. They should also incrementally add changes as they become more confident in the constructivist style (Hand & Vance, 1995). Some of the modifications teachers can make include:

- Provide lab activities before discussing the results students are expected to find;
- Discuss labs before lecturing on the topics;
- Remove lab data tables so that students generate or organize information;
- Change tests to require more concept application by students;
- Use a questioning strategy that encourages students to reveal what they're thinking;
- Have students invent the procedure to answer a lab question; and
- Put students into situations where groups debate, discuss, research, and share (Colburn, 2000, p.4).

Science education has also been willing to embrace the computer as a means of enhancing instruction, either through tutorials and simulations, integrating the World Wide Web into the curriculum, or using the power of the Internet to deliver online courses. A study of 10th grade students who worked in pairs using computer simulations and prediction sheets to enhance instruction revealed that students were able to work collaboratively and demonstrate gains in their conceptual understanding of mechanics (Tao & Gunstone, 1999).

Persin (2002) used web-assisted instruction to incorporate the World Wide Web into the curriculum and to improve achievement scores in his high school physics class. Student scores in his physics classes had fallen off of previous levels when his school switched to block four scheduling. To offset the drop in scores, he designed a class web site that provided the students with lecture notes, assignments, and provided links to other sites to investigate the physics topics. This allowed him to devote more class time to activities and consequently the students' achievement scores were increased.

In a more extreme example of using the power of the Internet to teach an online course, Lemckert and Florance (2002) were faced with the problem of incorporating a laboratory component into a distance education class. Their solution was to develop a solution they called Real-Time Internet Mediated Laboratory Experiments. In these, students used their Internet connection to manipulate a camera and an experiment in the science laboratory of the school. Although this does not provide the opportunity for the learner to gain experience with the apparatus itself, this method did provide the greatest amount of flexibility. The instructors believed it was superior to other methods of experiments in distance education courses such as substituting simulations or forwarding laboratory materials to the students.

Conclusion

Each new educational philosophy and each new technology desired to transform the lumbering behemoth that is education. Unfortunately, an institution as large as education has a tremendous amount of inertia preventing this change. The progressivists on the 1920's-1950's desired to move students out of desks that were bolted to the floor in rows and have them become more involved in a student-centered curriculum. They hoped that new technology such as the film projector would help transport students out of their traditional classrooms. Unfortunately, their accomplishments fell far short of their dreams.

The behaviorists of the 1950's through 1980's began where the progressivists left off, arguing for their own set of changes. They felt teaching and learning should be prescribed and by reinforcing the proper behaviors, learning could be improved. The behaviorists favored heavy use of the teaching machine to facilitate student learning. This panacea could provide the individual paced instruction that was impossible in the typical large group setting of a classroom. The teaching machine was afforded a meteoric rise in popularity followed by precipitous decline as it quickly faded from the favor of the educational establishment. This time period also oversaw the advent of the television as an educational medium. Once again, however, after a surge in popularity, instructional television began to fade rapidly.

From the 1980's until present there has been ever growing support for the constructivist viewpoint of education. A great quantity of research, especially in science education, has been completed that demonstrates students' understanding improved in classrooms where the teacher guided them and they were allowed to make meaning of the concepts for themselves. This era has seen the advent of new technologies to replace old ones, such as the VCR replacing the film projector, and has seen the growth of the single largest educational technology to date, the computer. As the computer has progressed, it has changed from a glorified teaching machine into a powerful educational tool capable of delivering entire degree programs. Each of the previously discussed eras lasted about 30 years, which would put constructivism and the computer on the downward swing from a historical trend point of view. It seems, however, that constructivism and especially the computer are still on the rise and will continue to be for the foreseeable future.

As for the future of the educational technology, most who glimpse into their crystal ball show the computer playing a prominent role. One vision of the future includes an increase in the amount of educational content that is provided via the WWW. This will coincide with increased broadband access to the Internet, particularly in homes (Smith & Broom, 2003; Weller, 2002). This will allow future online courses to "…evolve from 'talking heads' into more elaborate and interesting mixtures of lecturers, graphics, photos, demonstrations, video, and interactive problem solving" (Smith & Broom, 2003, p. 16).

Others, however, are much more pessimistic about the impact of the Internet on the future of education. As Chipman (2003) states, "…wiring the schools and making it possible for students to touch the Internet is not going to turn many student frogs into princes…" (p.47). In his book, *Oversold and Underused: Computers in the Classroom*, Cuban (2001) argues that despite the billions of dollars spent on hardware, wiring, and software, there has been little to no measurable return on this investment. Although he does concede that if present trends continue they "…will eventually yield exactly what promoters have sought: every student, like every worker, will eventually have a personal computer" (p. 196).

Most experts (Maddux et al., 2001; Smith & Broom, 2003; Weller, 2002) agree that there will be a continued trend to increase the number and availability of courses online. Weller (2002) argues that this will be analogous to the ability to watch movies at home on a VCR. As movies became available on tape, and now DVD, the movie industry has actually seen an increase, not a decrease, in ticket sales at theatres. So to will schools actually see an increase in enrollment on campus as students have greater access and ability to take courses online.

As for what educational technologies will lead the way into the next decade and beyond, my observations and research lead me to believe computing will move away from the desktop and toward a more mobile version. This may take the form of a traditional laptop computer, a version of the new tablet computer, or some form of a PDA (personal digital assistant). New technologies will need to have the ability to communicate wirelessly with networks at home and at schools or businesses. Traditional classroom barriers will continue to crumble as students and teachers begin to have the ability to communicate 24/7 with instant messaging, email, text messaging, and posting on class or personal websites.

All that is certain with educational technology is that it will continue to evolve and some teachers will continue to implement it faster than others. The past has shown us regardless of the extent a new technology is hailed as the 'next great thing' it is not guaranteed longevity or success in the classroom. The computer and its related technology of the Internet and the World Wide Web may break this trend. As the evolution of educational technology continues to accelerate we must keep in mind that "These changes call for new research on the effectiveness of technology (Tally, 1998), new research questions and new assessment instruments, and at a general level, new model(s) of research that can keep pace with the rate of technological change" (Perez & Bridgewater, 2003, p. 122).

This explicit call for additional research is another reason why it was important that this study be completed. While the Internet and constructivism seem to have more staying power than some of the past movements and technologies, just having them survive is not sufficient. Research, like this project, needed to be conducted to determine if the Internet could be utilized in new and effective ways.

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Chapter 3

Methodology

Role of Researcher

This study was framed from the author's perspective of a physics with the goal of trying to find new methods of delivering quality physics instruction where it is otherwise unavailable. This dissertation project tested the ability of an Internet delivered unit in physics on kinematics to deliver similar results as the same unit delivered by a classroom physics teacher. The objectives of the unit were set to match with the North Carolina Standard Course of Study as well as the National Science Standards. Specifically, it met the North Carolina Standard Course of Study by incorporating part of three different strands, Science as a Human Endeavor, Science as Inquiry, and Science and Technology. It also met the following competency goals (*NC Public Schools*, 2001):

1.01 Analyze velocity as a rate of change of position:

-Average velocity

-Instantaneous velocity

1.03 Analyze graphs to describe instantaneous velocity as motion at a point in time.

1.04 Analyze acceleration as rate of change in velocity.

1.05 Analyze graphically and mathematically the relationships among position, velocity, acceleration, and time.

Students who received the online instruction were not expected to outperform students who received instruction from a physics teacher. It was hypothesized that students would show reasonable gains in physics knowledge.

This opens the possibility for physics curriculum delivery via the Internet to be further explored as a possibility if a qualified physics teacher is unavailable.

Population

The population selected for this study was 150 high school physics students from five high schools in North Carolina. These high schools were chosen because they had physics teachers willing to participate in this study. The teachers were contacted through personal recommendations, listservs, and science outreach centers in North Carolina. Each of the five high schools had one teacher that participated in the project. See table 3.1 for a description of the students by school.

Three of the high schools were designated to receive the kinematics unit from their regular physics teacher. The teachers in this 'classroom' group agreed to teach the same subject unit as the 'online' group. These students completed the activities with laptop computers, motion detectors, and LabPro's that were provided for this project. The 95 students in this group aged in range from 15-18. They were 60% male, 79% Caucasian, and 13% African-American. All but one of these students was either a junior or senior.

The other two high schools were designated to receive the online curriculum. The teachers in these rooms were asked to do little in the way of instruction and to primarily provide technical support if the students were having difficulties. These students completed the activities on their schools' networked computers with motion detectors and LabPro's that were provided for this project. The 55 students in this group ranged in age from 15-18. There were 50% male, 75% African-

American, and 8% Caucasian. All of the students were either juniors or seniors in high school.

Table 3.1

Population Description

School	Group	Location	# Student	Gender	Ethnicity*
A	Classroom	Urban	35	63% M 37% F	91% C 9% AA
B	Classroom	Suburban	17	53% M 47% F	47% AA 29% C
C	Classroom	Suburban	43	60% M 40% F	88% C 10% A
D	Online	Urban	42	57% F 43%M	86% AA 5% C
E	Online	Rural	13	77% M 23% F	23% C 23% AA

* C= Caucasian, AA= African-American, A= Asian

A third much smaller group was also selected for the study. These were a group of home-schooled high school age students who volunteered for the project. Unfortunately, despite much prodding, they never completed the unit.

Data collection

Data collection for this project took place in three parts. Table 3.2 shows the links between the research questions and the data collection instruments.

Table 3.2

Data Collection for Research Questions

Research Question	Data Collection
Can a hands-on online physics unit be developed for high school physics students that is comparable to a hands-on physics unit taught by qualified physics teachers?	Pre- and Post-Unit TUG-K
Were there factors that were not physics related such as computer skill or familiarity with computers that were predictors of success in the online physics unit?	Pre-Unit Survey Post-Unit TUG-K
What were students' attitudes and views about physics during the computer-based physics unit, and did these views change?	Pre- and Post Unit VASS-Physics Post-Unit Survey Post-Unit TUG-K
What level of conceptual understanding of physics did these students possess, and was there evidence of any conceptual change?	Post-Unit TUG-K

The first part was a pre- and post-test given to the students covering graphical understanding in the context of kinematics. This test is called the Test of Understanding Graphs- Kinematics (TUG-K) version 2.6 (Appendix A) by Beichner (1998). It is a 21-question multiple-choice test that is both conceptual and computational in nature. This instrument has been tested extensively and has been shown to be reliable and valid (Beichner, 1994). Validity was established by giving versions of the instrument revised from field-testing to 15 science educators to complete and comment on the appropriateness of the items. Reliability was established statistically on the final version of the test with a population of over 500 post-instruction high school and college physics students. The KR-20 reliability statistic for the TUG-K was .83, well above the .70 required for a reliable test. Item reliability was shown by the Point-biserial Coefficient of .74, well above the .20 required for reliable items.

The second phase of data collection for this project were pre- and post-unit surveys designed by the researcher. The pre-unit survey (Appendix C) was designed to collect demographic information about the students as well as information about the students' computer use, computer comfort, and math and science background. The post-unit survey (Appendix D) asked the students to self-assess their own learning over the course of the unit. It also asked for their opinions on what they liked and did not like about the unit. Lastly, this survey asked the students how much and in what way this unit was different from science instruction they had previously received. Both of these surveys were reviewed by a group of experts in science education research for their reliability and validity.

The third point of data collection was another pre- and post-unit survey. This was the Views About Science Survey- Physics (Appendix B) by Halloun and Hestenes (1996a). This was a 30-item survey in a contrasting alternative design. In this type of design, a student is presented with a statement about physics and then given two contrasting choices agreeing or disagreeing with the original statement. Students may select either of the contrasting choices or make a selection on a continuum between them. There is also an option to choose neither of the contrasting choices. This survey was validated by being given to over 500 experts in the field (Halloun & Hestenes, 1996b).

An additional source of data was the student responses given during the online. These came from either answers to the questions in the unit that were emailed to the researcher or from postings completed online as part of discussions.

Each of the classrooms was recorded on a digital video camera monitored by the classroom teacher. The resulting videotapes were so inconsistent they were not explicitly analyzed.

Data Analysis

The data analysis of this project varied for the three different types of data that are collected. Each part, the pre- and post-TUG-K test, the demographic survey data, and the VASS survey data was analyzed in their own way. This did not preclude ideas that occur in one form of the data from carrying over and shaping the exploration of the next form of data.

The pre- and post-TUG-K data was analyzed with statistical tests to determine if there was a difference between the pre- and post-test as well as to determine if there was a difference between the groups. To determine if there was a significant gain t-tests of the pre- and post- test means were completed. To verify the results an ANCOVA was performed. Additional ANCOVA tests were used with pre-test as a covariate to determine the effects of other variables such as group. The post-test TUG-K data was analyzed for conceptual difficulties by comparisons with the results obtained by Beichner (1994).

The questions on the pre-unit survey that pertained to a student's prior computer use and comfort with the computer were analyzed with a mixed stepwise regression of the TUG-K post-test results. A tolerance level of $p= .25$ was chosen for the criteria level for variables to be added or removed from the model. Additional regression models completed in the same fashion were completed on subsets of the total, including dividing the students by group.

The VASS survey was analyzed from several perspectives. First the results were compiled and the distribution of the students' profiles were examined to determine the students' understanding of the nature of physics. Because of the ordered categorical nature of the data, a Wilcoxon signed rank statistical test was used to determine if there was a significant change of their views toward science after the unit. A Pearson chi-square test was used to determine if there was a difference between the groups on the pre- and post-VASS results. Additional ANCOVA tests were completed to determine if VASS results were related to achievement.

Ethics

The design and content of this study did not present any ethical dilemmas. All of the students and their parents signed consent forms to participate in the research. The students were never placed in any harm and their academic schedules were not interrupted. Throughout the course of the study, their normal classroom teacher always supervised the students. The classes were videotaped to provide the researcher a general idea of what occurred in the classroom, however, individual students were not identified or tracked on the videotapes. Student scores and responses on tests and surveys were recorded by a student-selected alias that was consistent for the length of the project. The students needed this identifier so that the pre- and post-test scores could be matched as well as the post-test scores matched to their demographic data. Actual student names were not collected as a part of this research.

The unit chosen for this study was consistent with the North Carolina Standard Course of Study. The unit used many commercially available materials and methods that are common in the physics classroom. It was the best guess of this researcher that the difference in the delivery methods of the students will not cause undue harm to the students nor cause one of the groups to fall irrevocably behind the other group in terms of their academic advancement in physics.

Generalizability

Ideally, the results of this study would be generalizable at least to physics students in North Carolina. Unfortunately, for a study to be generalizable the subjects must have been chosen randomly from a given population. Also, there must be a high enough number of subjects, or 'n' in the study. For this study, the subjects were not chosen randomly from the population of high school physics students in North Carolina. The schools that were chosen for this study were done so on a basis of the teacher and the school district being willing to participate in this research project. All of the teachers involved were recommended for the project by other researchers.

The actual student population in the research was hopefully representative of 'typical' physics classrooms. While the students were not a randomly chosen subset of the physics student population, the students did come from several different counties in NC. As described earlier, the physics population in North Carolina is a very small subset of the high school population.

While the randomness of the sample presented difficulties in generalizing the results of this study, the number of participants did not. One hundred fifty students completed the unit and the matched pre- and post- TUG-K test. The two groups that were compared, classroom and online, had 95 and 55 members respectively. These sample sizes were more than adequate to perform statistical analyses.

If other physics populations are deemed similar to the sample of these classes then a relatively high degree of confidence should be used for generalizing these results. If, however, other student populations or environments are very different than those described in this paper, then caution should be exercised when applying the results.

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Chapter 4

The Efficacy of Online MBL Activities

Introduction

High school students should take advantage of the opportunity to learn physics. Those students who do seize this opportunity deserve to be exposed to the preeminent teaching methods available because the conceptual understanding of physics by students is extremely low. Methodologies utilizing constructivist principles whereby students actively participate in the learning process have been especially effective at inducing conceptual change in students. The Internet can provide a medium through which constructivist teaching principles can be preserved and even enhanced.

Literature Review

The ability to solve complex problems and to understand modeling and estimation are skills that should be learned by students. These skills can be taught in a physics classroom (Redish, 2002). The best way for students to learn physics is to progress away from the traditional lecture and mathematical problem solving approach that has been used for so many years. In a study of over 6,000 students, Hake (1998) found that students who received physics instruction that promoted “heads-on” and “hands-on” activities performed more than two standard deviations higher than students who received lecture based instruction on conceptual and problem-solving tests in mechanics .

Physics instruction can deviate from traditional lecture in varying degrees. A small step from traditional lecture is the use of interactive lecture demonstrations. These demonstrations, which use student predictions coupled with real-time data projected to the class, have been shown to increase student understanding (Johnston & Millar, 2000). A larger step away from lecture was illustrated in a study by Chang (2001) involving 159 tenth grade students. Chang compared groups receiving problem-based computer-assisted instruction versus a more traditional lecture-centered approach. Students receiving the problem-based computer-assisted instruction scored significantly higher on knowledge and comprehension post-tests. Another instructional model differing from lecture and that will be described in greater detail later is what Redish (2000) classifies as research-based active engagement instructional methods.

Many of the methods listed above can be incorporated into a constructivist classroom. While research has shown that constructivist philosophies can be effective (Lord, 1999; McKittrick, Mulhall, & Gunstone, 1999; Yager & Weld, 1999), it can be carried to an extreme, known as radical constructivism. One interpretation of radical constructivism defines it as removing any form of teacher assistance, and instead relying on the student to assemble all knowledge, with no objective truth (Rezaei & Katz, 2002). In their study, Rezaei and Katz showed that inventive teaching, a mild form of constructivism where the teacher assisted students with their knowledge construction, significantly outperformed radical constructivism.

Another method not already mentioned explicitly that has been championed in education is that of computer-assisted instruction (CAI). Computer-assisted instruction is a broad term that relates to any intervention by a computer with a student. In an analysis of 24 studies involving CAI versus traditional classroom settings, Christmann and Badgett (1999) found an average effect size of .266 for

CAI. This meant students who received the CAI scored higher than 60.4% of the students in the traditional group. The effect size for CAI in physic classes was .280. In a more recent and broad meta-analysis, Bayraktar (2001) found 42 studies, with 108 different effect sizes, providing adequate statistics comparing CAI and traditional teaching strategies. The average effect size of these studies was .273. Another way of understanding this effect size is that it would indicate in a student an increase from the 50th to the 62nd percentile. Physics in particular had an effect size of .555. A more recent example of such a study would be the work completed by Kiboss (2002). One hundred eighteen students in Kenya underwent a six-month physics course on measurement. These students were divided into collaborative computer-based or traditional, primarily lecture, groups. The post-test analysis demonstrated better understanding by the collaborative computer-based group.

Besides the learning gains of CAI, students tend to enjoy and prefer this method of instruction over traditional lecture settings (Chang, 2002; Kiboss, 2002). For 27 consecutive semesters, students have rated CAI as the most helpful part of instruction in a physics course at the University of Illinois despite different instructors, different teaching styles, and different textbooks (Jones & Kane, 1994). Students who were left unguided with CAI were outperformed by both traditional students and students using the same CAI who were given guidance by their teacher (Ardac & Sezen, 2002).

Although CAI encompasses many different applications and treatments, the technology in any CAI system should be designed to fit the teacher, so that the teacher does not have to change to fit the technology. A well-designed system should make the technology transparent, allow for reinterpretation by different users, and utilize common technologies (Zhao, 1998). For example, in a study where the teacher had little technology training, no difference was found between the CAI and traditional classroom groups. On examination of videotape of the classroom, it was found that considerable amount of time was spent on learning and operating the technology (Duffy & Barowy, 1995).

The use of the Internet (or WWW depending on language used in a given study) is a newer form of CAI. Research has been conducted to see if it is feasible to teach science classes via the Internet. One important factor to determine was if the Internet was inherently biased against certain groups. Hargis (2001) determined factors such as age, gender, racial identity, attitude and aptitude do not have an effect on learning completed via the Internet. A second major concern, particular to science teachers, is teachers' interest in keeping laboratory activities in online classes. To date, the most common ways of managing this issue have been through the use of computer simulations, videos, the sending of lab materials to distant sites in kits and through the manipulation of laboratory equipment remotely through the computer (Forinash & Wisman, 2001).

The Internet can be used in the classroom for a wide variety of reasons. Reasons can include, but certainly aren't limited to; finding information, accessing tutorial or constructivist content, communicating, and collaborating (Bazley, Herklots, & Branson, 2002). More specifically for the physics classroom, the Internet is appropriate for applications such as showing graphics that promote understanding, and interactive applets where the students can change and control parameters (Clinch & Richards, 2002). Another example that utilizes the power of the Internet in the physics classroom, and ties the classroom to the real world, is to collect current data on social related physics concepts such as power consumption and power production (Hammond, 2002). The Internet can allow students to complete studies that are not normally possible or practical in a traditional classroom. Post-Zwicker et al. (1999) reported on a unit completed by high school students that involved the modeling and manipulation of topics relating to plasma physics. These students not only simulated experiments that would not be possible, they also were in contact with physicists throughout the duration of the project.

Use of the Internet can have benefits in the classroom beyond aiding in knowledge acquisition. Some of these additional benefits include learning different information presentation styles, the transparency of gender and race in online communication, and the fostering of creativity (Bazley et al., 2002). One study compared students who completed a traditional lecture class to those who researched a topic and constructed their own web page on the material. Those that created their own web page not only were allowed to express their own creativity, but at the end of the unit had changed their preferred learning style to one that favored questioning over the traditional lecture with which they were most familiar (Lin, Cheng, Chang, & Hu, 2002).

Shortly after the invention of the microcomputer, science teachers were taking advantage of this new technology. One of the methods was through the use of microcomputer-based laboratories (MBL's). Teachers who were given the opportunity to experiment with motion detectors for the first time reported envisioning uses in the classroom that ranged from replacing equipment in traditional reinforcement labs to developing concepts (Solomon et al., 1991). These activities use a sensor and the computer to collect and display, in real-time, data collected from an experiment. Teachers and researchers were quick to realize that besides aiding in the understanding of science concepts, this could also have a positive impact on students' ability to interpret graphs. Mokros and Tinker (1987) studied the effect of using MBL's on 125 seventh graders. These students were split into two groups and one group used MBL's in their science classes at least 20 times over the course of study. This group of students demonstrated significant gains versus the other group on a graph interpretation post-test, despite the fact they received no explicit instruction on graphs. Mokros and Tinker (1987) suggest four reasons for the effectiveness of MBL's:

> It is very likely the combination of these four factors (multimodal reinforcement, real-time linking of concrete and abstract, meaningful context, and elimination of drudgery) that contributes to the power of learning via MBL. When students are in control of a learning experience that they design, are given real-time feedback about that experience, and are freed from the painstaking task of producing a graph, they are in an ideal position to learn what a graph says and means. (p.382)

Shortly thereafter, it was determined that the real-time graphing feature of MBL's was indeed a critical component for student learning. If the graph presentation was delayed until the conclusion of the event, then the improvement effect on student outcomes by MBL's disappeared (Brasell, 1987).

MBL's quickly spread throughout the science education community and they were studied for many different effects. They showed no significant gains to graph interpretation in a biology classroom (Adams & Shrum, 1990) and no significant gains on the science reasoning skills of 8th graders (Friedler, Nachmias, & Linn, 1990). Women in a college physics class who were less inclined to like the computers at the beginning of the semester had equally positive attitudes toward them after a semester of MBL's (Laws, Rosborough, & Poodry, 1995).

MBL's continued to prove effective in producing conceptual change in physics students. When MBL's replaced small group problem solving sessions for mechanics students at the University of Maryland, performance significantly improved compared to traditional methods (Redish, Saul, & Steinberg, 1997). It was also found that the best way to use MBL's was in combination with having students predict the outcome of the experiments. Bernhard (2000) examined the use of MBL's with and without this element of prediction and established that using MBL's in conjunction with prediction produced higher levels of conceptual change in a university physics course for non-physics majors.

Research Questions

This research project combines constructivist approaches with MBL's within an Internet course. The MBL curriculum that was chosen for this study was the Tools for Scientific Thinking: Motion and Force units developed by David Sokoloff and Ronald Thornton (1998). Thornton began experimenting with MBL's in the classroom early after their development. He was especially interested in the use of the motion detector and its applications. He placed the motion detector and some sample lab activities into the hands of both sixth grade and undergraduate students and noticed how these two very different groups both enjoyed the activities, were engaged in the learning process and were able to quickly understand how to use the technology (Thornton, 1986, 1987a).

The development of the Tools for Scientific Thinking (TST) curriculum was the result of this work. Thornton (1987b) believed the motion detector and the MBL were ideal tools to encourage the inquiry needed in the physics classroom. The tools themselves, however, were not enough; they needed to be coupled in a pedagogically sound curriculum. Students would be active participants in the science process and encouraged to learn from peers. Students can easily extend the classroom activities to investigate topics in greater depth. The goals of the TST curriculum are to make abstract concepts more concrete through the immediate feedback provided, thus assisting the under-prepared student or the student with science anxiety. The TST curriculum was first tested with university physics classes, both calculus-based and non-calculus based, and was found to significantly decrease the number of misconceptions on kinematics graph interpretation and to significantly increase the retention of this material (Thornton & Sokoloff, 1990).

This study uses six investigations of the TST curriculum regarding motion presented in two treatments. First, it was presented in normal classroom setting with a physics teacher and the computer resources to necessary complete the activities. The second treatment included the computer resources to necessary complete the activities presented via a web site with minimal to no teacher interaction. This design was implemented to determine first; can high school students learn physics through the use of WWW-based MBL activities? Second, was there a difference between the WWW-based MBL units and classroom-based MBL units on kinematics?

Population

Participants included 150 North Carolina students. Fifty-five students from two high schools completed the curriculum online. These students are referred to as the online group. This group ranged in age from 15 (6%) to 18 (6%) and the students were in the 11^{th} (38%) or 12^{th} (62%) grade. There was an even split of 26 males and 26 females and they were 75% African-American. Forty-eight members of this group were currently enrolled in a math class with 25 (52%) of them in pre-calculus and 12 (25%) in calculus. The school year prior to this study, 14 (27%) students had completed pre-calculus and 20 (38%) had completed algebra II. They accessed a website designed by the researcher that placed the TST curriculum on the WWW. Students were presented with the same lab activities and directions. When these students answered questions their responses were sent to the researcher from the website. The teachers in these classes were requested to provide no help with the physics concepts, but were asked to assist with any technical difficulties. There is evidence that the teachers in this group did not assist the students with concept formation. One of the free-response reasons given several times for why this unit was different from their normal science classes was because their teacher was not available for help.

Ninety-five students from three high schools completed the curriculum in a traditional CAI manner. These students are referred to as the classroom group. They received paper copies of the labs and worked in groups of two to four people at a computer with a motion detector. Their physics teachers presented the curriculum to them and assisted them as needed throughout the duration of the study. This group ranged in age from 15 (8%) to 18 (3%) and the students were in the 10th (1%) through 12th (59%) grade. There were 57 (60%) males and 38 (40%) females and they were 78% Caucasian and 13% African-American. Seventy-three members of this group were currently enrolled in a math class with 31 (42%) of them in pre-calculus and 19 (26%) in calculus. The school year prior to this study 43 (46%) students had completed algebra III and 27 (29%) had completed algebra II.

Treatments

For both groups this unit took place within the first two months of the school year. Therefore, the students involved in the study had received minimal physics instruction on any topic, and no instruction on kinematics in the physics class where this unit was completed, prior to this unit.

The online group contained two schools from different areas in North Carolina. One school was a large urban school, and the other a smaller rural school. A teacher in each of the two schools volunteered their classes for participation in the project. Each teacher was provided with the motion detectors and LabPro interface devices, however, each of these schools provided their own online computers for use in the physics classrooms throughout the project. The teachers reported being familiar with MBL's but had not used the TST curriculum prior to this study. Two to four weeks were required to complete the unit. The teachers in the online group were asked not to help with the physics concept development of the students. This was requested to encourage the students to use the website, Internet, and peer resources to complete the activities. The Fysics Is Fun website had a set of links where the students could go for help. There were also multiple links for the students to reach the researcher electronically with questions or comments. The website included a section where the students were able to post thoughts, frustrations, and successes with each other. The TST activities themselves were identical to the classroom group except they were on web pages instead of paper. The students only used paper when directed by the website to print graphs so that they could make predictive sketches of the motion they were about to observe. The online group required more computer savvy from the students. They had to be able to move fluently between two windows, the browser window with the website, and the Logger Pro window that displays the real-time graphs created by the motion detector. They also were required to download and print the occasional graph as mentioned earlier. At the request of the teachers before the project began, the Fysics Is Fun website included a portion that supplemented the TST curriculum with an introduction to kinematics problem solving. The questions from the activities and homework of the TST curriculum were completed on the web and the answers were automatically forwarded to the researcher when submitted. The researcher scored these responses and sent them back to the classroom teacher to use as grades for the students.

The classroom group consisted of three schools from different regions of North Carolina. One teacher in each of the three schools volunteered their classes for participation in the project. Each teacher was provided with motion detectors, LabPro interface devices, and laptop computers. All of the teachers reported being familiar with using MBL's but had not used the TST curriculum prior to this study. Two to four weeks were required to complete the unit, and the teachers were asked to present the curriculum in their normal teaching style. Although the TST lab activities included directions, concept development, and homework, teachers were free, and encouraged, to 'teach' the students as they completed the labs. The teachers were requested to score the lab activities and use them as grades as they were completed.

Pre- and Post-Test

The test administered in this study was the Test of Understanding Graphs-Kinematics (TUG-K see Appendix A) by Beichner (1998). This test was born out of a study to determine if the learning gains from MBL activities were primarily due to the display of the real-time graphs or the kinesthetic creation of the graph coupled with the real-time display of the graph (Beichner, 1990). Beichner reported that the kinesthetic element of the unit in combination with the real-time graph display was significantly better than watching the event and the graph together.

Beichner (1994) further studied the validity and reliability of the TUG-K so that it could be used explicitly with MBL studies that relied heavily on graph interpretation to convey physics concepts. The test was revised several times and given repeatedly to high school, junior college, and university students. The KR-20 reliability statistic for the TUG-K was .83, well above the .70 required for a reliable test. The Point-Biserial Coefficient of .74, was well above the .20 required for reliable items. Fifteen science educators established the validity. The final version was administered to an additional 524 post-instruction high school and college students to establish the baseline data expectations. The mean score established for all students was 8.5 (40%).

Results

The pre-test mean on the TUG-K, with 21 as the top possible score, for the online group was 3.3 with a range from 0-11. The post-test mean on the TUG-K was 7.6, with a range from 2-18. The average gain score was 4.3 (see Table 4.1).

Table 4.1

Comparison of Pre- and Post-Test Test Scores of the Online Group (n=55)

	Mean	SD
Pre-Test	3.3	2.2
Post-Test	7.6	3.8

$p < 0.0001$

A one-tailed paired t-test showed there were significant gains from pre- to post-instruction. The resulting t-statistic had a p-value which was <.0001. This strongly suggests that learning occurred during the treatment period for the online group. While the mean post-test score, 7.6, is still relatively low for a test of 21 questions, it is near the mean level, 8.5, established for the TUG-K by *post instruction* high school and college physics students.

A similar analysis of the classroom results showed that there was also a statistically significant improvement in their scores (see table 4.2).

Table 4.2

Comparison of Pre- and Post-Test Scores of the Classroom Group (n=95)

	Mean	SD
Pre-Test	5.9	3.8
Post-Test	9.4	4.3

$p < .0001$

A one-tailed paired t-test of the classroom group resulted in a t-statistic with a p-value that was < .0001. This also strongly suggests that learning occurred for the classroom group during the treatment period. Figure 4.1 shows the distribution of pre- and post-test scores for both groups combined.

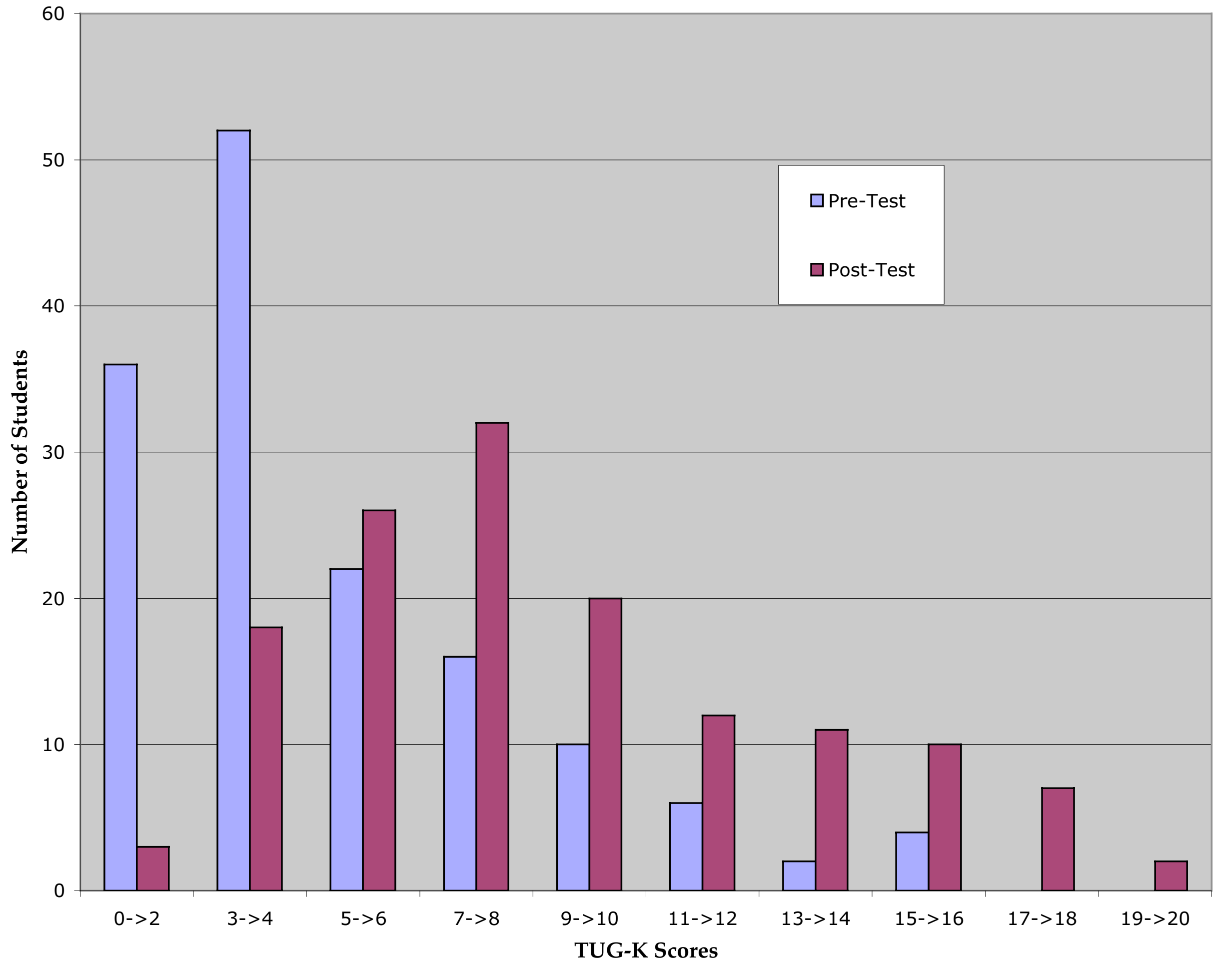

Figure 4.1- Combined Groups Distribution of Pre- and Post-Test Scores

T-tests were preformed to determine if there was a difference between the groups on the pre-test, the post-test and in gain score (Table 4.3).

Table 4.3

Comparison of Online and Classroom Groups (unequal variances)

	t	DF	Prob>|t|
Pre-Test Score	5.157	145.975	<.0001
Post-Test Score	2.602	112.116	.0105
Gain Score	-1.482	99.6129	.1415

There is a significant difference, $p < .05$, between the online and classroom groups in both the pre-test and the post-test. There is not a significant difference, $p > .05$, between groups on the gain scores (See Figure 4.2).

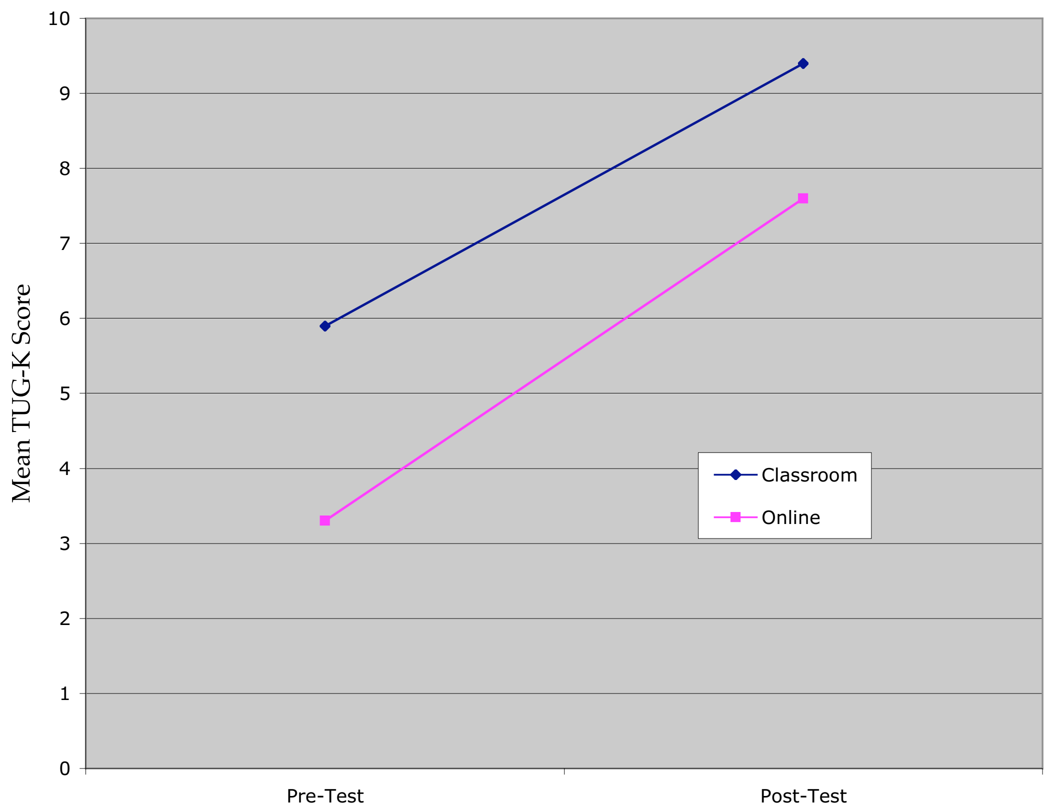

Figure 4.2- Mean TUG-K Scores by Group

These statistical tests suggest that the classroom group started and ended with higher scores, but that the gain, or amount learned by each group was not significantly different. This suggests that unit was equally effective for both groups.

A second statistical analysis was completed to confirm these results. An ANCOVA was performed to compare the groups on the post-test, using the pre-test as a covariate. The first model fit included an interaction term for whether or not the groups differed in the relationship between post-test and pre-test. The result of this test, p = 0.4666, indicated that the interaction was not significant, and the cross-product term between the variables was removed from further analysis.

The ANCOVA results (Table 4.4) indicate similar results as the t-test. When examining the post-test score and controlling for an individual's pre-test score, there is not a significant difference between the groups. This suggests that the amount of learning exhibited by both groups was similar, and that the difference in post-test scores is a consequence of the classroom group having started at a higher pre-test score.

Table 4.4

ANCOVA of Post-test on Pre-test and Group

Source	DF	Sum Squares	F Ratio	Prob> F
Pre-test	1	1129.6	120.84	<.0001
Group	1	5.1036	.5460	.4612

One of the concerns of this study was that the treatments were taking place in five different schools, with five correspondingly different teachers, and that some of the effect could be attributable to school instead of group. Indeed, in an ANOVA on pre-test by school, there was a significant difference between the schools. The difference broke the schools into three groups. School A, was the highest and different from the second school, School B. School B was different from the next three schools, Schools C, D, and E, which were all similar. The classroom group contained school A, school B, and one school from the third group. Both of the online schools were in the third group. In a similar analysis with the post-test score, only school A was significantly higher than the other four schools, which were all similar.

To determine if school had an effect on achievement, an ANCOVA analysis was completed in a similar manner as was carried out with the variable group. First, the post-test was analyzed in a model including a cross-product term between school and pre-test to determine if there was an interaction between these variables. This was not significant and omitted from subsequent analyses. When post-test was modeled by pre-test and school (Table 4.5) it was determined that school was not a significant factor. The p-value, .23, indicates that once you control for the pre-test score, the school attended by the individual is not a significant factor when determining the post-test score.

Table 4.5

ANCOVA of Post-Test on Pre-Test and School

Source	DF	Sum Squares	F Ratio	Prob > F
Pre-Test	1	1075.8	116.89	<.0001
School	4	52.432	1.4242	.2293

Beichner (1994) established that there was a difference in achievement on the TUG-K according to gender. A t-Test was preformed on the pre-test, post-test and gain scores by gender (Table 4.6). There were significant differences between the genders on both the pre- and post-test. The gain scores, however, were not significantly different.

Table 4.6

t-Test of Gender (with unequal variance)

	Mean (F)	Mean (M)	t-Test	DF	Prob > |t|
Pre-Test	3.918	6.067	-3.735	127.75	.0003
Post-Test	7.431	10.11	-3.744	124.85	.0003
Gain	3.517	3.900	-.706	123.81	.4818

An ANCOVA of the post-test scores controlling for pre-test and gender (see Table 4.7), completed in a similar manner as those on group and gender, confirmed these results.

Table 4.7

ANCOVA of Post-Test on Pre-Test and Gender

Source	DF	Sum Squares	F Ratio	Prob > F
TUG-K Pre	1	1047.6	114.7	< .0001
Gender	1	22.4	2.4	.12

Discussion

The results indicate that neither gender nor school significantly affected the post-test performance of a student once the pre-test score was controlled. Most importantly, for this study, it also indicates the presentation mode of the MBL activities did not significantly affect their performance. It is important to note that most studies that compare CAI with normal or traditional classes, no computers are involved in the normal or traditional study. This study was unique; it compared different degrees of reliance on the computer when using CAI. When using a well-designed constructivist-based curriculum with MBL's involving the students kinesthetically and displaying real-time data, students' computer abilities are sufficiently sophisticated to take the complete instruction from the Internet with no decrease in the quantity of learning that occurs.

This study also indicates that both groups gained understandings of kinematics through the graphs they created as tested by the TUG-K. It appears as if the amount of learning for both groups may not have been as high as desired, however, the mean for both groups on the post-test was 8.79. This compares favorably to the mean found by Beichner (1994) of 8.5. Beichner's TUG-K baseline mean was obtained from a combination of high school and college students after the completion of a physics course. The 8.79 mean obtained in this study was for high school students only who were in their second month of physics instruction.

Neither the design nor the results of this study were intended to imply that teachers are not a critical component of the classroom. A quality teacher provides students with many aspects of support that a computer cannot. A teacher can be a mentor, a role model and even a friend in time of need. A teacher can sense the mood and emotional needs of a student that a computer cannot. A teacher can monitor students working in a group to find the individual that is not participating or not understanding the material.

The results of the study do, however, suggest some exciting opportunities for web-based instruction. The marriage of MBL curriculum and the online environment is relatively unique. MBL physics curriculum, when designed with constructivist principals, has been shown by itself to be equivalent or better than traditional, here meaning lecture-based, physics classroom settings. This study has shown that online MBL curriculum is not significantly different from traditional, teacher led, MBL curriculum.

Schools in many regions across the country have difficulties finding physics teachers; especially ‘highly qualified’ physics teachers. A method of physics instruction that is online and involves the use of MBL equipment could be an avenue that schools can pursue if they cannot fill physics teacher vacancies. This could be especially attractive to small high schools that may only have a handful of students interested in pursuing a physics class.

This study also offers direction for additional research. One of the limitations of this study was that the online group had a teacher present who was asked to be a technician only. It would be useful to test this approach in an environment that is truly void of a physics teacher. Another area that needs further direction is the content of the unit itself. The TST curriculum has two parts, Motion and Force, and Heat and Temperature. Of those, only the motion component was part of this study. If this were to indeed be expanded to a full physics course these units would be good starting points, but more curriculum using similar pedagogy would have to be developed to encompass all that is learned in a year of high school physics.

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Chapter 5

Correlates of Achievement with Online and Classroom-based MBL Physics Activities

Introduction

The ability to predict the success or failure of a student in a class is a very powerful tool. If specific skills are highly correlated with success then every effort should be made to ensure that all students have these necessary skills. If a lack of certain skills correlates highly with failure, then students should receive remediation until their skills match those of the students likely to succeed. Studies have been conducted using a wide variety of both intellectual, socio-emotional, and background variables in an attempt to predict students' success or failure. These studies have been conducted in an effort to help teachers understand their students, to assist college and universities in selecting students to enter their institution, and for advising students what classes are necessary as prerequisites to afford students their largest opportunity for success. This study examined if there were any traditional or computer-related variables that could predict success in a computer-based physics unit.

Review of Literature

Much of the research pertaining to correlating success or failure with certain variables was completed in the 1970's and 1980's. This may have been partially in response to high profile reports that linked student success with socio-economic background. In a review of the current literature of the time, Margrain (1978) concluded that little variance could be explained after accounting for general intelligence. Much of the research produced mixed results, as different variables accounted for different portions of the variances in achievement. Another difficulty in identifying a consistent set of variables was the wide variety of indicators of success used in the different studies as the dependent variable. The inclusion of variables outside the realm of the school, such as socio-economic and other background variables, also did not consistently explain student variances in success.

> However, the large amount of still unaccounted for variance in student performance suggests that the students might not be the sole arbiters of their success. Their teachers' ability, personality, bias, methods, and numerous variables associated with the institution attended must also be conconsidered [*sic*] for complete and accurate prediction of academic performance. (Margrain, 1988, p.121)

Predictor variables have also been consistently used by colleges and universities to find attributes of students that can be used for admission policies. The most typical variables used for admission are standardized test scores, such as the ACT or SAT, and high school performance. These two variables, however, also show a discrepancy as to how well they predict the success of a student at a university. The highest levels of correlation are formed under certain conditions. The students need to stay in dorms on campus, their freshman class has to have a relatively small enrollment, 500 or less, and have above average standardized test scores that have a large standard deviation (Munday, 1970). More recently, an examination of these same variables, standardized test scores and high school performance, found that they correlated well with students' academic performance at institutes of higher learning, but did not hold any predictive value for students' interest or enjoyment of their studies (Harackiewicz, Barron, Tauer, & Elliot, 2002).

Many departments and colleges within a university also use correlations attempting to predict students' success in their programs and to determine at what level they should be placed within the program. A study of engineering students revealed that the single best variable for predicting success was math achievement (Levin & Wyckoff, 1988). In an effort to determine why only 40% of males and 33% of females persisted in the natural sciences through graduation, the students' achievement in mathematics was again the single best indicator (Adair, 1991). The combined variable of high school G.P.A and ACT score was the best predictor of student achievement in a series of college English and math courses (Noble & Sawyer, 1989). This correlation was then used to suggest models for placing incoming students into the math and English curriculum at the appropriate level.

When completing correlations or predictive models, one of the confounding variables is gender. In some cases gender correlates with success (Okpala & Onocha, 1988), and in other instances it does not (DeBoer, 1985; McCammon, Golden, & Weunsch, 1988). One commonality in several studies, however, is that women can be more accurately correlated with success than men (McCammon et al., 1988; Munday, 1970). In their study, McCammon et al. found a correlation for all the students in a second year physics course, however, when they attempted to correlate the men and women separately, no factors predicted success for men, and the correlation for women was much higher than the entire group.

Attempts were also made to determine different variables for men and women that would correlate with success. In a study with a low population of females (females = 23, males = 96) predicting success in high school physics, Ignatz (1982) found that males preferred a divergent structure. This structure provides for a greater variety and quantity of 'right' answers. Females, on the other hand, preferred convergent structures. This structure worked toward finding one correct answer. Studying characteristics of males and females who succeeded or failed in their first college science class, DeBoer (1985) found the characteristic of rashness, as defined by the Omnibus Personality Inventory, was positively correlated with success in men and negatively correlated with success in women. The same study showed women who considered themselves hard working and goal orientated were the most likely to succeed.

In a study that is somewhat indicative of those in this area, Edge and Friedberg (1984) correlated a variety of academic and biographical variables with achievement in a first year university calculus class. In this case, none of the biographical variables, including gender were significant. The best indictors were an algebra pre-test score and high school rank. Edge and Friedberg, (1984) thought that class rank could be more than an achievement measure, "It may in fact be the case that rank in class represents a measure of competitiveness as well as a characteristic of long-term emotional adjustment…" (p.140)

In a survey of over 1800 eighth through twelfth grade students, males responded as being more interested in computers, more confident in their computer ability, and less likely to feel that computers could have a negative impact on society than females (Collis, 1985). After completing a computer course, males had a more positive attitude, and females a less positive attitude, toward computers. The same study linked math and science attitude as a mild predictor of computer attitude. A study of over 2000 students in Israel found no link between science achievement and the amount of time spent using a computer (Tamir, 1987). An obvious method for students to increase their computer ability is through enrolling in computer courses. According to research by Campbell and Williams (1990) the most effective computer course for high school students is enjoyable for the students yet they feel that it is useful and it has an environment that alleviates the fear of failure.

Wang and Newlin (2002) examined 122 college junior and seniors who enrolled in online sections of a course to determine if their reason for enrolling in a web-based course affected their achievement. Not surprisingly they found that the students who wanted to enroll in the online sections, as opposed to those who enrolled because it was the only available section, received higher grades in the class. They also found technology and subject content self-efficacy and how actively a student used the course website also correlated positively with success in the course. A different study, with a very small population, n=18, found students who indicated they believed class discussion was not helpful were more engaged, as measured by use, on the course website (Moan & Dereshiwsky, 2002). They also suggested learning styles did not correlate with engagement on the website.

Because students at every level often struggle with physics, many studies have been completed to determine what factors contribute to success in a physics course. An investigation of over 400 students in Nigeria correlated variables with physics success (Okpala & Onocha, 1988). The top four correlates were, in descending order, math ability, attitude toward physics, word knowledge, and study habits. Griffith (1985) examined the effects of formal reasoning and math skills on physics achievement in introductory university physics course. Formal reasoning, math ability, and effort all were strongly correlated with achievement.

Finding variables that consistently account for the variance of success within a population is a difficult task. A study predicting success in an Australian physics course yielded a different list of significant variables from one year to the next (O'Halloran & Russell, 1980). One variable that is consistent in predicting success in physics, however, is math ability (Champagne & Klopfer, 1982; Griffith, 1985; Hudson & McIntire, 1977; Hudson & Rottmann, 1981; O'Halloran & Russell, 1980; Okpala & Onocha, 1988; Wollman & Lawrenz, 1984). In a study of over 900 students who completed a college physics course, math ability by itself was able to account for almost 42% of the variance in the final grade. Interestingly, while math ability correlates very well for success in physics, it does not correlate well with students who drop out of physics courses. Wollman and Lawrenz (1984) and Hudson and Rottmann (1981) both found that math ability was not a significant correlate with the likelihood of a student to drop out of a physics course. This suggests that while math ability is important for a student to succeed in physics, many of the students who are failing to complete physics courses are doing so for reasons other than not having sufficient mathematical backgrounds.

Champagne and Klopfer (1982) correlated variables not to physics achievement in general, but instead to achievement only in the section of physics known as mechanics. They used a variety of assessment instruments to define three variables; math aptitude, science experience, and degree of Newtonian physics understanding. An especially discouraging component of this study was that science experience and Newtonian physics understanding were included as separate variables because:

> The finding that the Years of High School Physics variate is not significantly related to the *Newtonian physics* variables may be taken as an indication that students' exposure to high school physics courses has little effect on their acquisition of the particular knowledge, understanding, and skills that are the components of this variable. (p. 307)

The conclusion of this study, not surprisingly based on the above statement, was that math ability and Newtonian physics were the two variables that correlated significantly with achievement in physics.

Research Questions

This research was unique because not only was it trying to find variables that would correlate with and predict success in a high school physics unit, but it also looked specifically at variables related to the method of delivery of the class. An earlier study by the author indicated that in an university chemistry class that used the WWW for homework quizzes and class exams, the students' computer use and comfort were significant predictors of their success (Slykhuis & Banks, 2004). In the present study, the curriculum in the high school physics units was entirely computer-assisted and partially web-based, therefore the analysis included several computer related variables. The investigation determined what variables were significant predictors of success in a high school physics unit that utilized computer-assisted instruction. More specifically, this study examined if any computer related variables were significant, particularly for the subset of the group that completed all the activities online, or were the best predictor variables the traditional variables described in the literature, such as math ability.

Population

This study was completed with 150 students at five different high schools in North Carolina. Ninety-five students received their instruction in a normal classroom microcomputer-based laboratory (MBL) setting. These students worked in groups with laptop computers and motion detectors. The teachers in these classrooms actively helped the students to develop their physics understanding. Fifty-five students received the entirety of their instruction online. These students also worked in groups with computers. The teachers in these classes agreed to not offer instruction on the physics concepts. The students were to develop their understanding from the activities, their peers, and the additional resources found on the course website. While the students ranged in age from 15-18, 88% of them were either 16 or 17. All but one student was either a junior or senior in high school. The students were 56% male, and 53% Caucasian and 35% African-American. One hundred forty-one (96%) of the students had a computer at home, and 136 of those computers were online. A majority of the students, 60%, indicated they used the Internet daily, and only 4% reported using the Internet about once a month. Figure 5.1 shows the distribution of the students' responses to their computer comfort on a 1-10, 10 being highest, scale.

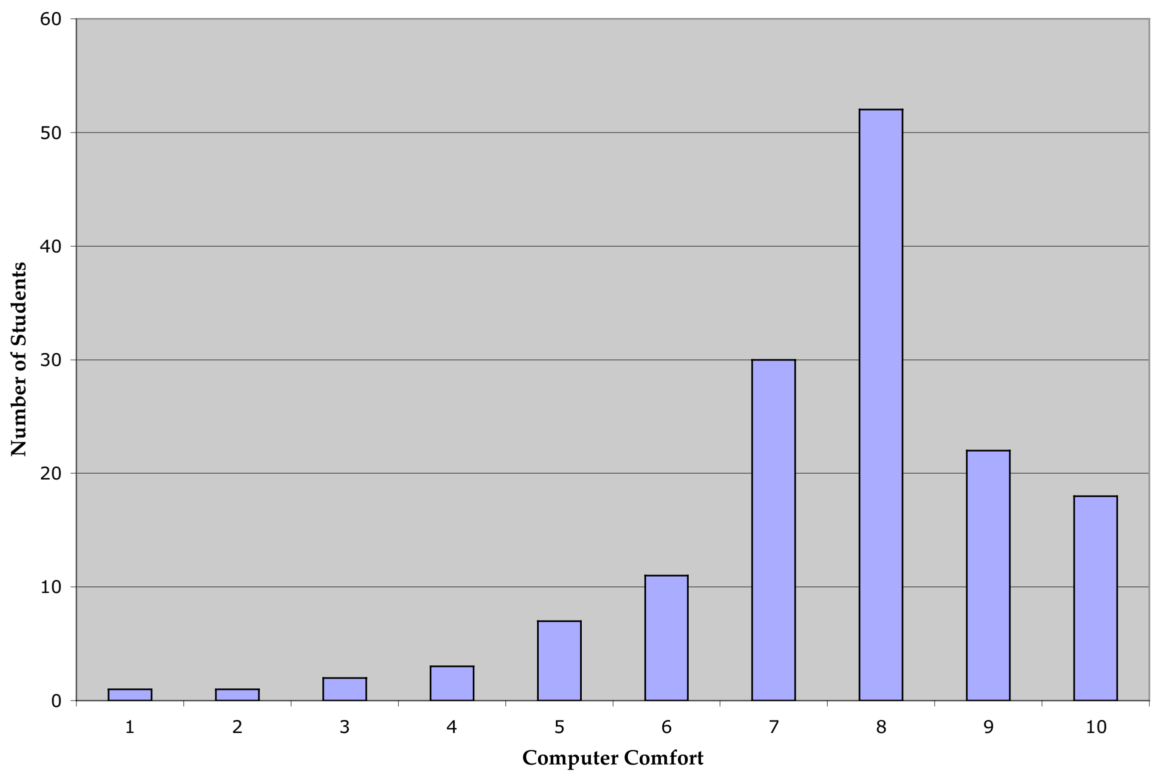

Figure 5.1- Distribution of student responses to computer comfort

Only 38% of the students had completed physical science, while 89% had completed chemistry. One hundred twenty-one students reported being currently enrolled in a math class, while 145 reported completing a math class last year. Figures 5.2 and 5.3 show the distribution of those math courses.

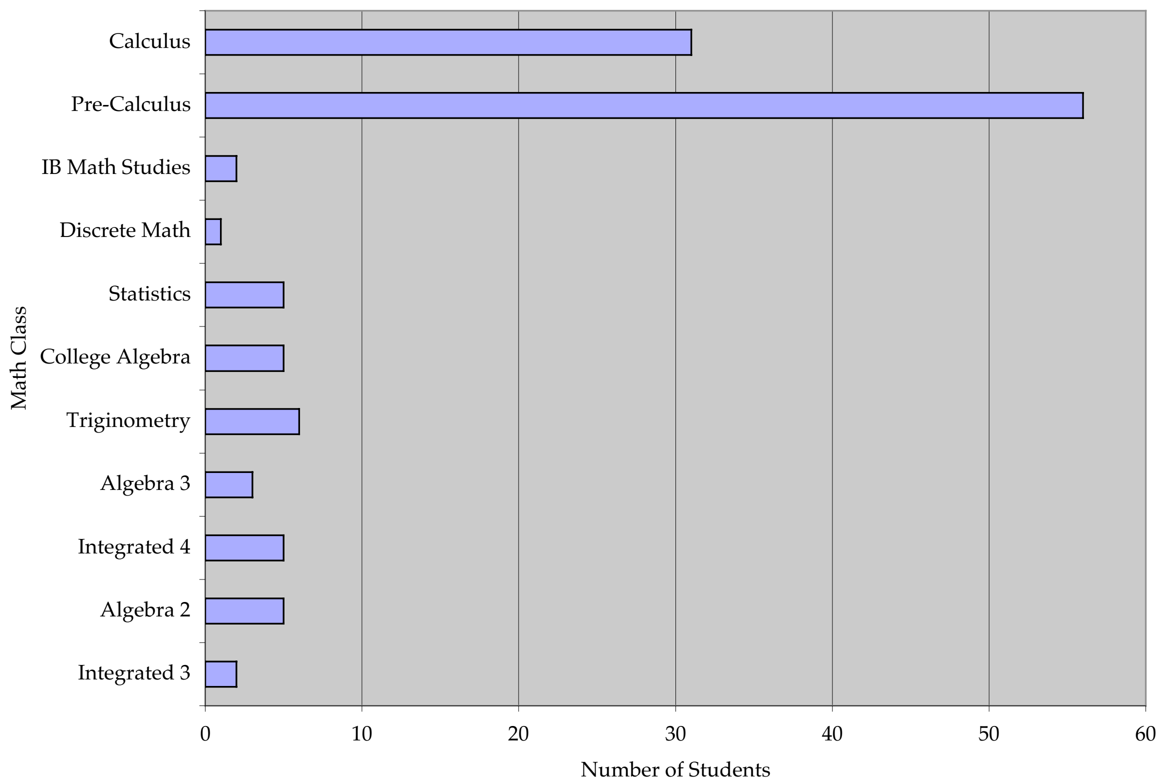

Figure 5.2- Distribution of students' current math class

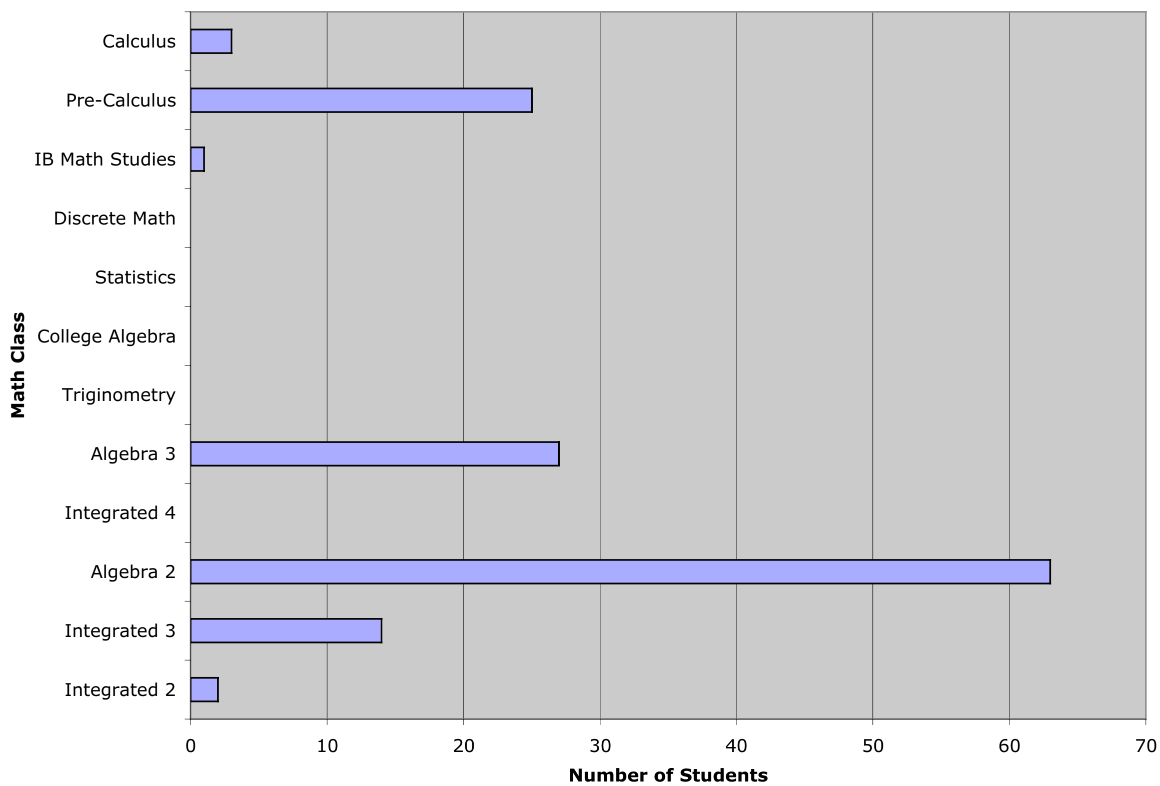

Figure 5.3- Distribution of students' last completed math class

Method

The 150 students described above all participated in a two to four week unit on kinematics. All of the students completed the first six investigations of the Tools for Scientific Thinking- Motion curriculum by Sokoloff and Thornton (1998). This curriculum uses microcomputer based laboratories (MBL's) to teach physics concepts. Prior to instruction, all of the students completed a survey asking for a variety of demographic data as well as information about their computer use and comfort. Students also completed a pre-test of their kinematics physics knowledge, the Test of Understanding Graphs- Kinematics (TUG-K see Appendix A) (Beichner, 1998). This test was developed by Beichner (1994) explicitly to test MBL activities. The KR-20 reliability statistic for the TUG-K was .83, well above the .70 required for a reliable test. The Point-Biserial Coefficient of .74, was well above the .20 required for reliable items. Fifteen science educators established the validity. This same test was used at the conclusion of the unit as a post-test to measure the students' achievement.

A student's score on the TUG-K post-test was used as the dependent variable in this study. The traditional independent variables were age, gender, race, year in school, prior physical science experience, prior math experience, and their score on the TUG-K pre-test. The pre-test was included in the model as a measure of aptitude in this particular topic studied during this unit, kinematics.

Some of these variables were created through a compilation of students' responses given on the survey. If students had previously taken physics, physical science, or chemistry, was combined into one variable that related their physical science experience. To determine students' math experience, they reported their current math class and the last math class they had completed. The twelve responses given to these questions were placed in one of four categories based on the level of the math class. Each student was then given a category score from one through four corresponding to the level of the course. The other change was to the category of race. Since this was an open-ended self-reported question, a wide range of answers were returned. These were combined into three categories, African-American, Caucasian, and other races.

Variables that were particular to computer use and comfort on the survey included: 1) if there was a computer at the student's primary residence, 2) if that computer was connected to the Internet, 3) if they had ever taken an online course, 4) how often they used the Internet, and 5) their comfort level with a computer. The variable relating the frequency of Internet use provided the students with five choices, once a month, twice a month, once a week, two or three times a week, or once a day. This was then coded as a 1-5 response. The variable asking them to self-report their computer comfort-level was answered on a one to ten scale. Before the analysis was completed simple correlations between the numerical independent variables were examined (see Table 5.1) to determine if any of them were so highly correlated as to be redundant.

Table 5.1

Correlation of independent variables

	Year	Comp.	Internet	Online	Internet Use	Comp. Comfort	Phy. Sci. Exper.	Math	Pre-test
Age	.75	-.14	-.21	.05	-.32	-.12	.16	-.21	-.27
Year		-.06	-.10	-.05	-.31	-.19	.06	-.18	-.27
Computer			.65	-.10	.20	.14	.02	.04	.13
Internet				-.02	.38	.17	.04	.04	.21
Online					.16	.11	-.03	-.07	-.11
Internet Use						.51	.05	-.16	.24
Computer Comfort							.09	-.00	.13
Phy. Sci. Experience								.19	.08
Math									.03

Note: all values rounded to two decimal places

Not surprisingly, two sets of variables were highly correlated and logically seemed redundant. A high correlation existed between a students' age (Age) and their year in school (Year). Subsequently, age was removed from any further analysis. A high correlation also existed between the variables reporting if a student had a computer at their primary residence (Computer) and if that computer was online (Internet). Therefore, the variable Computer was omitted from the analysis and the variable Internet was retained.

Stepwise regression was performed on the data collected from all 150 students that completed the MBL units. Separate regression models were then created for the online group and the classroom group to determine if completing the lab activities entirely online increased the reliance on computer related correlates. Lastly, in an effort to repeat prior literature, separate regression models were created splitting the entire group on the basis of gender to determine if these variables could more accurately explained the variance in achievement of female students.

Results

The stepwise regression to create the model that would explain the most variance was completed in a mixed progression fashion with the significance level for acceptance set at .25. This meant that the variable with the lowest p-value was entered first, and then subsequent variables with p-values less than .25 were added to the model. If at anytime, however, one of the variables that had been added to the model no longer remained significant at this level, it would be removed from the model. While these levels of significance are greater than the typical .05 value, they will help generate the most parsimonious model that explains the variance. The model was also restricted to only add whole effects. This meant that for any categorical variable, all or none of the categories had to be added. This method was found to be consistent when crosschecked by a model where variables were added individually in order of their significance to maximize the adjusted R^2 value.

The first regression model was constructed to account for the variance on the post-test for the entire group (n=150). In this model, three variables were added according to the chosen parameters, pre-test, current math category, and gender.

Of these, only two variables were significant at the $p < .05$ level: Pre-test ($p < .0001$) and current math category ($p = .0033$) (see table 5.2). Gender was the variable with next most significance and helps to explain the variance in achievement. Therefore, it was kept in the model as a weak correlate. The full model accounted for 56% of the variance on the post-test.

Table 5.2

Correlates with Post-Test for all Students

Variable	Initial p-value	Final p-value	R^2
Pre-Test	< .0001	<.0001	.497
Current Math	.003	.005	.555
Gender	.206	.206	.560

Note: The R^2 values are cumulative as that variable is added to the model. The initial p-value is the value at the time it was entered. The final p-value is the p-value after all the variables have been added.

Next, a similar mixed stepwise regression was applied to the classroom (n=95) and online (n=55) groups separately. This was completed to determine if an increased reliance on computers for instruction, the online group, is more highly correlated with any computer related variables than the classroom group.

In the regression model for the online group more variables were involved, possibly because of the smaller sample size. Table 5.3 shows all of the variables added to the model. Once again, only pre-test and current math were significant indicators ($p < .05$) of achievement when initially added to the model. When the model was complete, however, pre-test and gender were the only significant variables. The current math category was nearly significant with a p valued of .056. The variable Year, which represents the grade level of a student, was added to the model after the variable Gender, but was removed after the variable Internet Use was added because its level of significance at that point became more than the threshold level of .25. Variables that related the completed math class of the student, if the student had Internet access at home, and if they frequently accessed the Internet were all mild contributors to the model. Altogether, this model accounted for nearly 63% of the variance on the post-test by the online group.

Table 5.3

Correlates with Post-Test for the Online Group

Variable	Initial p-value	Final p-value	R^2
Pre-Test	<.001	.003	.330
Current Math	.016	.056	.506
Gender	.063	.007	.549
Year	.202	Removed	.569
Completed Math	.213	.105	.621
Internet Use	.214	.103	.639
Internet	.189	.189	.647

Note: The R^2 values are cumulative as that variable is added to the model. The initial p-value is the value at the time it was entered. The final p-value is the p-value after all the variables have been added.

For the group that completed the MBL's in a regular classroom setting, the pre-test score ($p < .0001$) and current math ($p = .021$) initially were the only significant ($p < .05$) variables. At the conclusion of the model, however, Pre-Test, Current Math, and School are significant, with Year just above this level (see Table 5.4). This model explained nearly 63% of the variance on the post-test by the classroom group.

Table 5.4

Correlates with Post-Test for the Classroom Group

Variable	Initial p-value	Final p-value	R^2
Pre-Test	< .0001	< .0001	.529
Current Math	.021	.020	.589
School	.127	.020	.609
Year	.055	.055	.627

Note: The R^2 values are cumulative as that variable is added to the model. The initial p-value is the value at the time it was entered. The final p-value is the p-value after all the variables have been added.

The identical technique was completed after dividing the group by gender. For the subset of female students (n=66), only pre-test was initially significant ($p < .05$). The last completed math class, year in school, race, and computer comfort, were all subsequently added to the model. Table 5.5 shows the complete model. This model accounted for 54% of the variance on the post-test by female students.

Table 5.5

Correlates with Post-Test for Female Students

Variable	Initial p-value	Final p-value	R^2
Pre-Test	< .0001	< .0001	.428
Completed Math	.134	.058	.468
Year	.194	.093	.484
Race	.146	.084	.520
Computer Comfort	.108	.108	.544

Note: The R^2 values are cumulative as that variable is added to the model. The initial p-value is the value at the time it was entered. The final p-value is the p-value after all the variables have been added.

The last multi-directional stepwise regression was completed for the male subset (n = 83) of the entire group. For this group, once again pre-test and current math class were the initial significant indicators of achievement. Unlike other groups, however, those were the only two variables needed to describe the variance in the post-test (see table 5.6). These two variables accounted for 56% of the variance on the post-test by the male students.

Table 5.6

Correlates with Post-Test for Male Students

Variable	p-value initial	p-value final	R^2
Pre-Test	< .0001	< .0001	.487
Current Math	.030	.030	.560

Note: The R^2 values are cumulative as that variable is added to the model. The initial p-value is the value at the time it was entered. The final p-value is the p-value after all the variables have been added.

Discussion

For this study, factors were correlated with post-test scores after completing a MBL unit either in the classroom or online in a 2-4 week time period. For the entire group of students, their score on the pre-test and their current math class explained 56% of the variance in the post-test achievement. This pattern was repeated for each of the sub-sets examined. This concurs with the majority of the literature in physics indicating math ability is a primary correlate for physics achievement. It was somewhat surprising that the math variable that was significant was current math instead of completed math. This unit, and the related testing, was completed at the beginning of the school year so students would not have had the opportunity to progress through much curriculum in their current math class. It is not surprising that the pre-test accounted for such a great deal of the variance. A student who shows aptitude in this area of physics, as indicated by a high pre-test score, is also likely to do well on the post-test. Gender was a non-significant ($p > .05$) correlate with achievement, with male students scoring higher than female students, for the entire group.

The second focus of this project was to determine if the two groups, who had various degrees of reliance on the computer, had different correlations with achievement specifically regarding computer related variables. Once again, pre-test and math ability were the primary indicators of achievement for both group. Two computer related variables were included in the analysis of the online group. Both Internet and Internet Use were non-significantly ($p > .05$) correlated with achievement on the post-test. Despite the fact the online MBL unit was completed entirely from a computer and near the beginning of the semester, a student's aptitude in the subject material (kinematics) but not the medium (the computer) appears much more important in determining a students' success than the computer related variables accounted for in this study. A total of 65% of the variance was accounted for using this model.

The last focus of this study was to determine if prior research could be repeated and females could be more succinctly correlated with success in physics. This does not seem to be the case in this study. While the model for female students accounted for 55% of the variance in post-test score in the final analysis, five non-significant variables were necessary for this conclusion. The only variable that was initially successful for the female group was the pre-test, which accounted for 44% of the variance. In contrast, 56% of the variance for achievement of the post-test for the male students was accounted for with only two variables, both of which were significant, pre-test and current math level. This suggests that whether or not females can be more accurately correlated with success needs further study.

Overall, these regression tests confirmed that achievement in physics is highly correlated with aptitude in the subject, as given by the pre-test score, and their mathematical level. Interestingly, the variable of the students' physical science experience was only weakly correlated for female students and did not appear in any other models. For all physics students, regardless of the format of the class, this implies that their mathematical preparation continues to be one of the most important characteristics in determining their success in a physics class.

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Chapter 6

Summary of and Changes in Student Attitudes and Views towards Physics during a Computer-based Unit

Introduction

Science education is no longer an effort to pass along a set of scientific facts to a new generation. Science teachers are also now expected to impart to students an understanding of how science 'works'. This additional element has been added into nearly all levels of standards and curriculum documents. Unfortunately, while there is agreement that understanding the nature and process of science should be included, there is much less agreement as to what this actually entails! One last task added to the science classroom is to bestow upon on the students an enjoyment of science, presumably so that students will remain in science fields. It might seem reasonable to believe students who complete science courses will learn more about the process of science and learn to enjoy science. As will be illustrated, however, that is often not the case.

Review of Literature

Trying to define the nature and process of science, especially physics, is not an easy task. In interviews with 20 physicists, Becher (1990) found they did not believe a physicist could be defined by a single stereotype. These physicists also considered physics a very open-ended subject driven by a sense of competition. They felt selecting appropriate problems was crucial and that physicists were concerned with recognition. Walker (1979) opined that physicists were only perceived as one of three stereotypes; a Frankenstein mad creator, a Nutty Professor, or an egg-head.

In a discussion of why anyone would become a scientist, Li (1999) stated the ideal of science was to understand nature and pursue truth. In fact, Li was adamant about the detachment of science, stating "Moreover, science, in its purest form, is supposed to be the disinterested, objective, and cooperative search for the truth, in front of which personal prejudice, vanity, and ambition should take second place" (p.20). As a student, Moravcsik (1977) agreed with these ideas, believing science was rigorous, unambiguous, and meant to uncover truths. After twenty years in the science field, however, he believes there are many more dimensions to science and that it is more collaborative in nature. His views changed to the point where "…I have come to recognize, to take great pleasure in, and to highly treasure the role of intuition and artistic creativity which plays such an important part in scientific productivity" (p. 33).

In reviewing the literature on the nature of science, Meichtry (1993) established that an understanding of the nature of science was necessary for proper appreciation of new science ideas. Meichtry also found that students typically had what was perceived as a low to moderate understanding of the nature of science, while scientists and science teachers had a relatively high and consistent view of the nature of science. Most alarmingly, instruction in science and science textbooks most often had a negative impact on students understanding of the nature of science. In a comparison of small groups (n=32) of students from Canada, America and Australia, Griffiths and Barman (1995) revealed that American students' view of science was very closely tied to textbook definitions of the scientific method.

Courses that add a focus on the process of science can improve the views of students (Gabel, Rubba, & Franz, 1977). Pre-service elementary school teachers who participated in a physics class that made explicit the process of science and included observations of science processes being taught fostered a better understanding of science and attitude. Another example of improving students' views about science was demonstrated by Galili and Hazan (2001). In a high school physics class concentrated on the historical development of concepts, students learned the physics concepts and obtained a more realistic view of the scientific process.

The importance of a person's view of the nature of science may not, however, be as important as first thought when considering decision making about science related issues (Bell & Lederman, 2003). Two groups of university professors, one with a higher understanding of the nature of science, were presented with a variety of science issues and problems. The reasoning and decisions reached by both groups were nearly identical, regardless of the development of their view of the nature of science.

Fostering a positive attitude toward science is no easier accomplished or defined than is understanding the nature of science. Attitude research in science education has been muddled at best (Koballa, 1988). There has been little consensus on the definition of attitude and certainly none as to the effects of attitude. What is known is that attitudes are enduring, learned, depend on beliefs, and related to behavior. Attitude was not related to type of curriculum, traditional or problem-based, in a study in Israel (Novick & Duvdvani, 1976). After a year of physics instruction, 11th grade students were less open-minded toward physics and found it less enjoyable (Gardner, 1976). This result was consistent regardless of the teacher or the teaching style.

Lawrenz (1976) found the perception of the learning environment was an accurate predictor for student attitude in both biology and chemistry. In physics, however, there was no correlation of attitude with learning environment. An improved attitude in physics was instead correlated with a more challenging physics course. This was confirmed in a study in Denmark as students in a more challenging physics course had more positive attitudes than those students in a less rigorous course (Nielsen & Thomsen, 1988).

Before trying to change student attitudes, it is important to understand how students, and those with influence on students, perceive physics. In a study of Australian university level physics students, Briggs (1976) revealed that roughly half the students taking physics were doing so to fulfill a requirement and only half were taking the course because they were interested in physics. Most of these students found the lecture portion of the course to be uninteresting, however, they enjoyed research activities. In an examination of people with influence over students' science choices, Redford (1976) discovered that high school principals and guidance counselors valued chemistry and biology above physics. Redford also found that principals and guidance counselors had, on average, more course credits themselves in chemistry and biology than physics.

Particular attention has been focused upon female students in attempts to foster positive attitudes to retain students in science fields. Females account for only about 25% of high school physics students, and this drops even more alarmingly to about 10% of students pursuing a physics PhD (Blin-Stoyle, 1983). In a survey of over 300 students in Israel, all students viewed physics as a masculine subject. Girls had a positive attitude in relation to chemistry but a negative attitude toward physics. Ziegler and Heller (2000) attempted to help retain females in physics through attribution training with 146 eighth grade girls. At the end of the study, the girls felt less helpless, were more motivated, and had a higher interest in physics.

Achievement has often been linked to attitude, presuming that a more positive attitude will lead to higher achievement. In a meta-analysis of the available literature, Willson (1983) found no consistent correlation between attitude and achievement. Students in grades 6-10 had mild correlations with achievement, however, from grade 12 through college no connection between attitude and achievement existed. Oliver and Simpson (1988) obtained similar results in a longitudinal study of over 5000 North Carolina students. Equating attitude to whether or not a student likes science, they found attitude was not a significant indicator of achievement. In fact, as time progressed, attitude continued to weaken as an indicator of achievement. In a correlational study of achievement in a college physics class, attitude was found to play no role in predicting student success (Willson, Ackerman, & Malave, 2000).

Research Questions

This study focused on the attitudes and views of physics students during a microcomputer-based laboratory (MBL) unit. This unit was somewhat unique in that two different groups participated in the project. One group of students completed the MBL activities in their normal classroom setting with the assistance of their teacher. The other group completed the same MBL activities entirely in an online environment.

The first objective of this study assessed the attitude of all the participating students completing the unit. This included determining if they enjoyed the activities, if they felt that learning took place, and if this unit was different from other school science they had completed. Along with this, any differences between the groups in terms of attitude and perception of the course were sought to determine if completing the unit entirely online effected students' attitudes.

The second objective measured the students' views about physics. This was completed to determine if the students hold views of physics similar to physicists and physics teachers. Next, it was determined if students' views about physics changed over the course of the unit. Of particular interest was finding if students' views became less sophisticated as a result of instruction as was suggested in the literature. Lastly, the students' views on physics and their achievement on a post-test of physics concepts were compared to determine if there was a relationship between views of physics and achievement.

Population

The sample for this study consisted of 150 high school physics students from North Carolina. These students attended five different high schools from different regions of the state. Ninety-five of the students from three of the participating schools completed the MBL units in a normal classroom setting. This classroom group of students was 60% male and 73% Caucasian. They were almost entirely juniors or seniors in high school. Fifty-five students from two of the participating high schools completed the unit online. This online group of students was 50% male and 75% African-American. This group consisted entirely of junior and seniors in high school.

Method

Teachers were recruited to volunteer their classes for MBL activities on motion. The curriculum used was the Tools for Scientific Thinking- Motion (TST) units created by Sokoloff and Thornton (1998). This curriculum had been tested and proven to increase students' understanding of and enjoyment of kinematics (Thornton & Sokoloff, 1990). Based upon available resources, each teacher's class was placed either in the classroom or online group. All of the teaching and learning for this activity took place over a 2-4 week period within the first two months of the school year. The students had not received any prior instruction on motion in this course.

The schools in the classroom group were provided with laptop computers and LabPro interfaces and motion detectors as needed. The teachers in this group were asked to have their students work in groups and complete the TST unit. They were given a suggested calendar and provided with all of the TST activities. These teachers were encouraged to provide assistance to the students as needed and to 'teach' this unit in their normal style.

The schools in the online group were given motion detectors and LabPro interfaces as needed. These schools provided their own online computers. The teachers in this group were asked not to assist the students in their conceptual development. Students were encouraged to work cooperatively and to use the website designed for this course to complete the activities.

Instruments

All of the students in this study were given a pre- and post-test assessing their knowledge of kinematics and associated graphs. The assessment for this was the Test for Understanding Graphics-Kinematics (TUG-K see Appendix A) developed by Beichner (1998). The KR-20 reliability statistic for the TUG-K was .83, well above the .70 required for a reliable test. The Point-Biserial Coefficient of .74, was well above the .20 required for reliable items. Fifteen science educators established the validity. All of the students also completed a series of pre- and post-unit surveys. First, a pre-unit survey developed by the researcher collected a variety of demographic data (see Appendix B). Before instruction students also completed the Views About Science Survey- Form P12 (VASS see Appendix D).

Halloun and Hestenes developed the VASS. The VASS uses 30 questions to determine if a students' views on physics are similar to those of experts in that field

(Halloun, 1996; Halloun & Hestenes, 1996a, 1996b). In order to create an instrument that could be used on large scales, yet retain validity and reliability; they developed a new type of question called contrasting alternating design. With this type of question a respondent is presented with a statement about physics and then two contrasting responses. The respondent then has the option of selecting either one of the responses in its entirety or can choose a combination of the two answers. Answers are given on a scale of one to seven, where an answer of four is an equal mixture of the contrasting responses. Respondents can also select a response, eight, that is neither of the contrasting responses. To evaluate the responses of students, Halloun and Hestenes gave the VASS to professionals in the field of physics. Physicists' and physics teachers' responses were very similar and were grouped jointly as experts. Respondents' answers are compared to the compiled results of the experts and then are assigned to one of four profiles. Items that match the experts are scored as expert opinions, responses that are opposite of the expert view are scored as folk views, and responses between the expert and folk view are categorized as mixed. If 19 or more items match the expert view, then an Expert Profile (EP) is assigned. Scoring 15-18 items as expert view results in a High Transitional Profile (HTP). Eleven to fourteen expert views are scored as a Low Transitional Profile (LTP) provided folk views did not out number the expert views. Scoring 10 items or less as expert views or having 11-14 items scored as folk views results in a Folk Profile (FP). Halloun and Hestenes (1996a) found that students with higher level profiles, EP or HTP, earned higher grades in college physics courses.

In the present study, students were given the VASS again after a two to four week instructional unit to determine if there was any change in their view of physics over the course of the unit. Students were also given a survey designed by the researcher (see Appendix C) to determine their attitude toward the unit. This survey was examined by a group of university science educators for reliability and validity. The survey also asked students to assess their own learning during this unit, to identify their favorite and least favorite parts of the unit, and what they did and did not enjoy about using the computer.

Attitude Results

Reports of student enjoyment and their self-assessment of learning on the post-unit survey were used to assess attitude. The first method to determine the students' attitude toward the unit was to assess on the post-unit survey if they enjoyed the unit and if they liked using the technology. Figure 6.1 shows the distribution of student responses on a one (low) to five (high) scale of enjoyment. While 150 students participated in this study, only 138 post-unit surveys were returned. This may have been because the post-unit surveys were given on the last day of instruction and the completion rate was considerably lower than any other measures given during the study. The mean response value was 3.04 (SD= 1.15). Sixty-eight percent of the students scored the unit as a 3 or above.

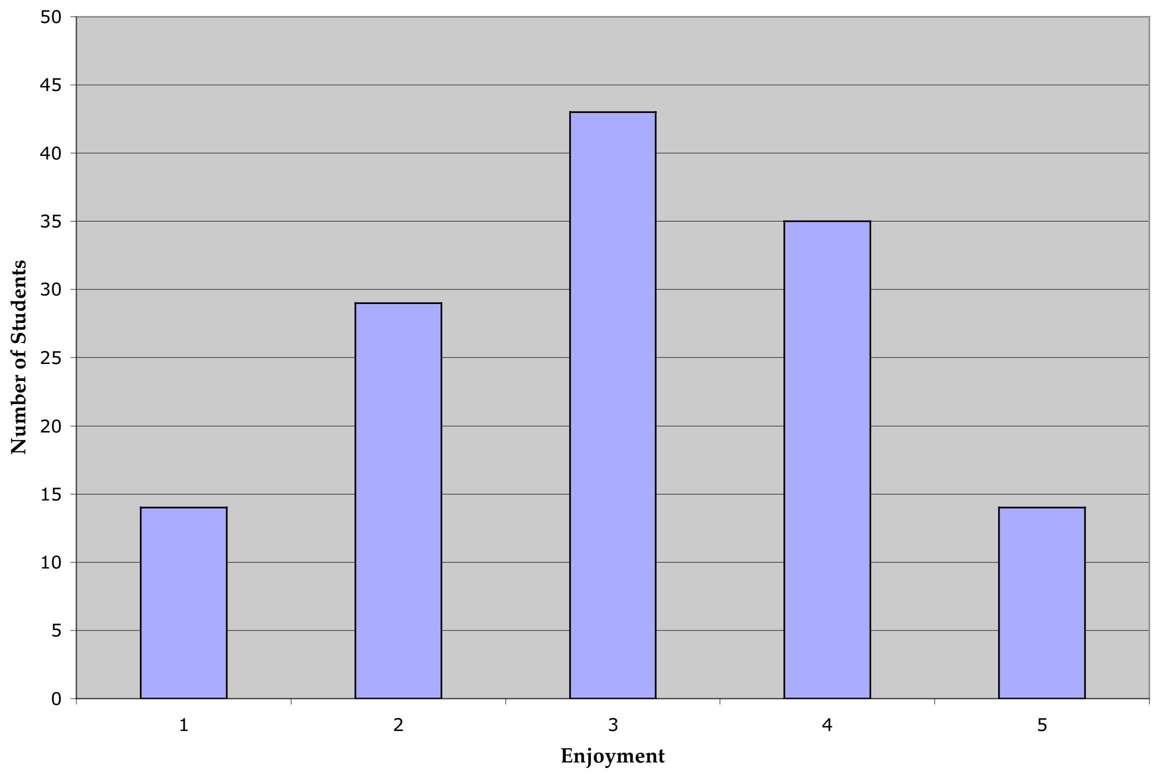

Figure 6.1 Distribution of Student Responses to Level of Enjoyment of Unit

Students were given four response options to assess their perceived gain in understanding of physics upon completion of this unit. The response choices were; not much, a little, quite a bit, and a lot. These were coded as 1-4 responses, with one for 'not much' and four for 'a lot'. The mean response was 2.54 (SD= .82).

Students were also asked if they enjoyed using the computers during this unit and if they had any computer problems. Eighty-two percent of the students reported enjoying using the computers for this unit. The students also completed a free-response prompt to explain what aspect of the computers they most enjoyed. While the responses were greatly varied, 25% of the responses were related to having the computer generate the graphs automatically. Students also reported liking the computers because they felt that it was faster and easier (9%). Fifty-seven percent of the students reported computer problems. By far the majority of these were non-systematic connection difficulties between the motion detector, LabPro, and computer.

Students were also asked to assess if this unit was different from other science classes they had completed. To determine if the unit was different, students selected one of three choices, about the same (7.2%), somewhat different (34.8%), or a lot different (58.0%). The most common response as to why it was different was overwhelmingly related to the daily use of computers and technology. In the online group, a common response involved the lack of a teacher interaction as a major difference.

This study also investigated if any of the above-mentioned variables related with the attitude of students in this project differed between the two groups, online and classroom. Table 6.1 displays a compilation of the data discussed so far for the entire group, classroom group, and online group. The p-values indicate if there were significant differences between the two groups. The variables Enjoyment, Learning, and Different, as described earlier were treated as ordinal variables and the Wilcoxon Rank Sum test was used to calculated the p-value. The variables Like Computers and Computer Problems were treated as nominal value and the p-value was calculated from a chi-square test. Students' reported enjoyment and perceived learning differed between the groups.

Table 6.1

Summary of Means for Groups

	All Students	Classroom	Online	p-value
Enjoyment (1-5)	3.04	3.45	2.44	<.0001
Learning (1-4)	2.54	2.86	2.04	<.0001
Like Computers (1= yes, 0= no)	.82	.85	.78	.27
Computer Problems (1= yes, 0= no)	.57	.62	.48	.11
Different (1-3)	2.51	2.46	2.57	.41

Additional understanding of the attitudes of the students in the online group can be garnered from comments made by students onto an online bulletin board during the project. Several of the postings by students referred to their enjoyment of the unit, their perceived learning and the use of the computer technology. Referring to how much they enjoyed the unit and the technology, one group wrote:

> We like the fact that we get to talk with each other. It is a joint cooperation assignment. The equipment helps us with the graphs. We do not have to predict anything and everything is exact. And it is fun to experiment with the technology on our free time.

Another group felt, "Yes, it is fun that we can interact with one another and use technology and use the internet to do classwork." With regards to assessing their own learning one group wrote, "We enjoyed working with the carts the most, they gave better data readings. We haven't learned anything from the given experiments so far." As to whether this unit was different from their other classes, one group said, "You need to use the book to learn the basics before using technology and furthering the learning process." Another group added, "The worst part of the activities was there was not a person guiding us through it. The website was pretty good overall because it was easy to navigate."

VASS Results

The second thrust of this study was to analyze the results on the VASS-physics. Only students who completed both pre and post-surveys, n=109, were included in the analysis. This included 71 matched pairs for the classroom group, and 38 for the online group. On the pre-unit VASS, an equal number of students, 17, were categorized as having the Expert Profile (EP), as were as having the Folk Profile (FP). The profile with the largest number of students was the Low Transitional Profile (LTP) with 47 students. The remaining 28 students were categorized as High Transitional Profile (HTP).

On the post-unit VASS students shifted from the LTP category to the FP category. After instruction 30 students were categorized as FP, and 33 were LTP. The two higher categories experienced little change. A nearly identical number of students were classified as EP, 18, and HTP, 28. Figure 6.2 compares the pre- and post-unit profiles for all students.

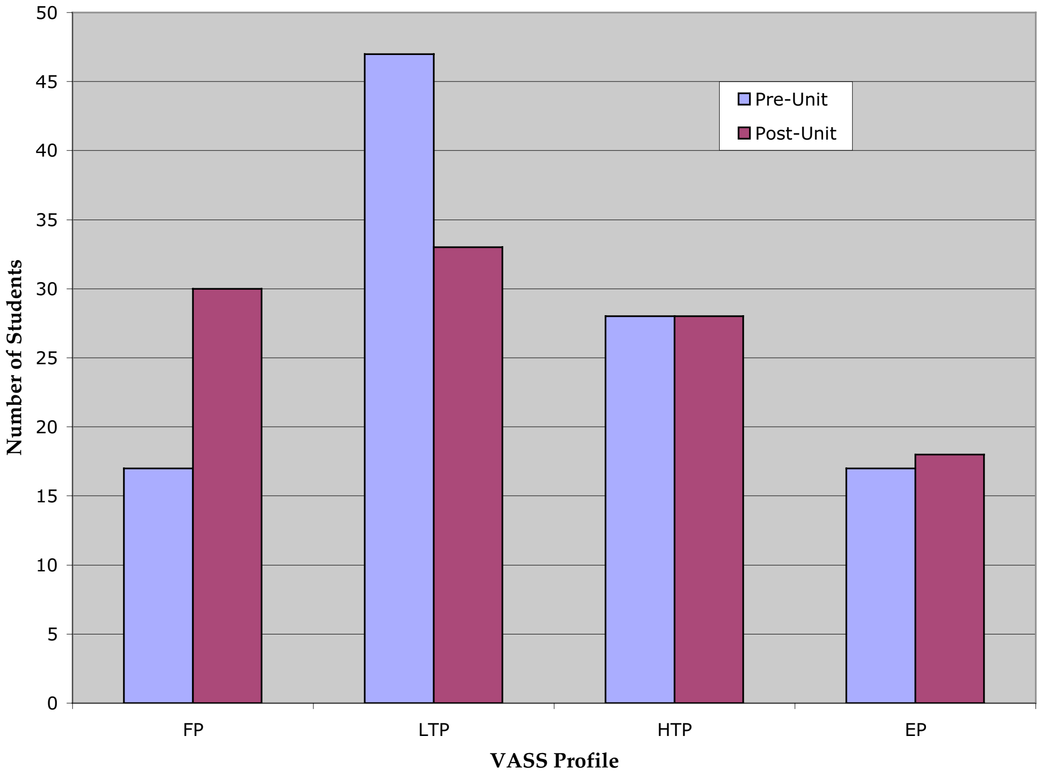

Figure 6.2 Distribution of Pre- and Post-Unit VASS Profiles for All Students

To determine if there was a difference in the pre- and post-unit VASS distributions, a Wilcoxon signed-rank test was performed (Table 6.2). In order to complete this test the data was transformed into numerical data. A FP was assigned a value of one, and an EP a value of four. This was completed for both the pre- and post-unit VASS scores. A VASS gain score was then calculated by subtracting the pre-unit value from the post-unit value. A hypothesized mean of zero was used in the test, as this would indicate no change from pre- to post-unit. The observed mean of the VASS gain was -.12. The Wilcoxon signed-rank p-value was .11 for a one-tailed test to determine if this was a significant decrease. A one-tailed test for a decrease was used based on the literature review indicating the sophistication of student views about science often decreases after instruction. This p-value indicates that while the distributions appear to have changed, there was not a significant decrease in the overall VASS profile of the students.

Comparisons were also completed for the pre- and post-unit VASS results dividing the students on basis of group, online or classroom. First, a Pearson chi-square test was completed to determine if there was difference between the two groups on the pre-unit and post-unit VASS. The p-value for the chi-square test for the pre-unit VASS and group was .32, indicating there was not a significant difference in the distribution of the students across the four profiles between the two groups. The Pearson coefficient for the post-unit VASS and group was also .32, again indicating there was not a different distribution between the two groups.

The next set of analyses examined the pre- to post- unit changes in VASS profile for the two groups. The classroom group (see Figure 6.3) became more evenly distributed across all profiles, including an increase in EP, on the post-unit survey. The online group (see Figure 6.4) shifted toward the FP, as every category except FP remained constant or decreased from the pre- to post-VASS.

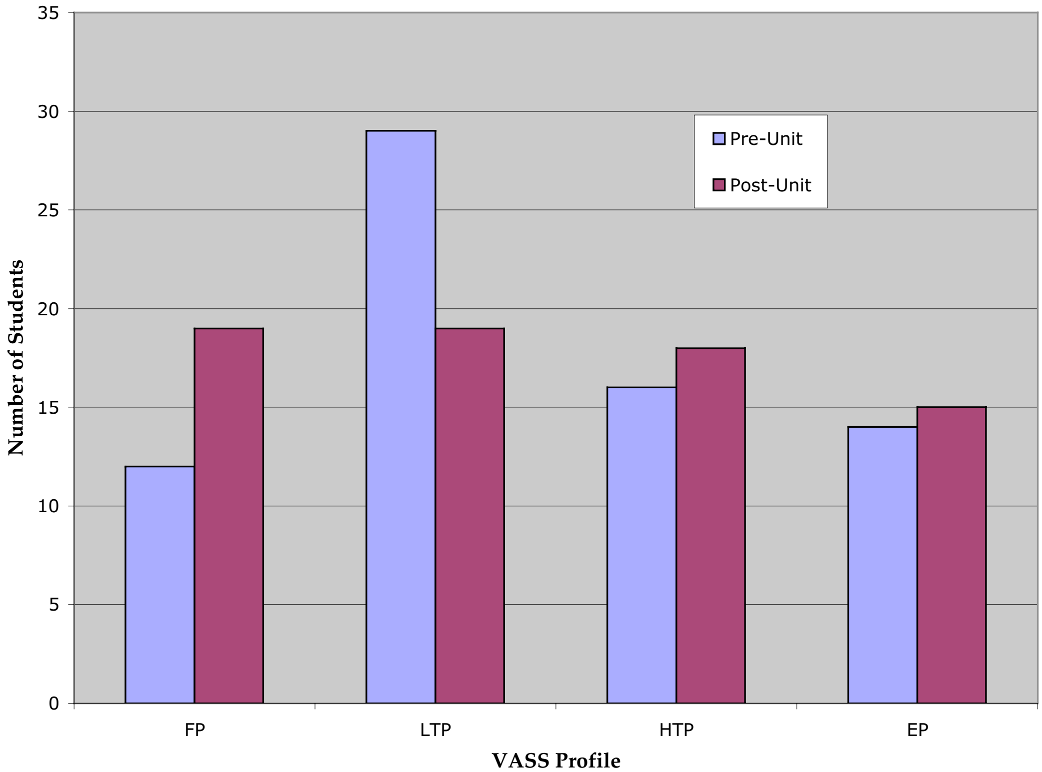

Figure 6.3 Distribution of Pre- and Post Unit VASS Profiles for the Classroom Group

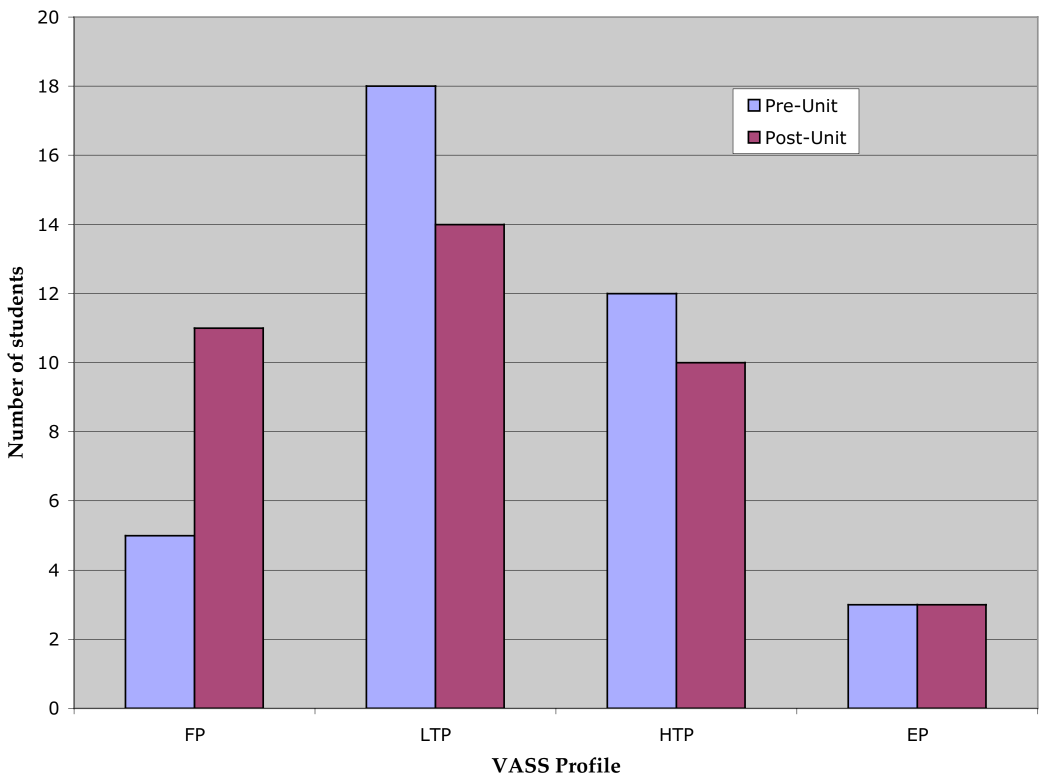

Figure 6.4 Distribution of Pre- and Post Unit VASS Profiles for the Online Group

Similar Wilcoxon signed-rank tests were performed on the classroom and online groups separately. The calculated mean VASS gain score for the classroom group was -.07. This was not a significant decrease from pre-to post unit (p = .25). The calculated mean for the VASS gain score for the online group was -.21. This also was not a significant decrease (p = .11). All of the Wilcoxon tests are summarized in Table 6.2.

Table 6.2

Summary of Wilcoxon Signed Rank Tests

	All	Classroom	Online
Mean VASS gain	-.12	-.07	-.21
Prob < t	.11	.25	.14

To determine if there was a difference in achievement based on a student's VASS profile an ANCOVA was performed. Post-test score on the TUG-K was used as the measure of achievement, and pre-test score on the TUG-K was included as a covariate. First, a model was fit including an interaction term for whether or not the profiles differed in the relationship between post-test and pre-test. The result of this test indicated that the interaction was not significant, and the cross-product term between the variables was not included in further analysis. A model was then constructed with the variables of pre-TUG-K and the pre-unit VASS profile. The results of this test are shown in table 6.3. This model indicated when controlling for the pre-TUG-K there was not a significant difference between the VASS profiles categories with regards to achievement.

Table 6.3

ANCOVA of Post-TUG-K on Pre-TUG-K and Pre-VASS

Source	DF	Sum Squares	F Ratio	Prob > F
Pre- TUG-K	1	706.22	74.18	<.0001
Pre-VASS	3	9.59	.34	.80

A similar analysis was completed to determine if there was a connection between Post-VASS profiles and achievement. Again, the post-TUG-K was the measure of achievement and pre-TUG-K was a covariate. The first model determined if there was an interaction between pre-TUG-K and post-unit VASS. The result of this test indicated that the interaction was not significant, and the cross-product term between the variables was removed from further analysis. A model was then constructed with pre-TUG-K and post-unit VASS. The results of this analysis are shown in Table 6.4. The p-value of .03 indicates that there is a significant difference between the post-unit VASS categories and achievement.

Table 6.4

ANCOVA of Post-TUG-K on Pre-TUG-K and Post-VASS

Source	DF	Sum Squares	F Ratio	Prob>F
Pre-TUG-K	1	711.44	80.99	<.0001
Post-VASS	3	88.06	3.15	.03

Figure 6.5 illustrates how achievement varied according to VASS profile. The mean score on the TUG-K post-test represents achievement for each post-unit VASS profile.

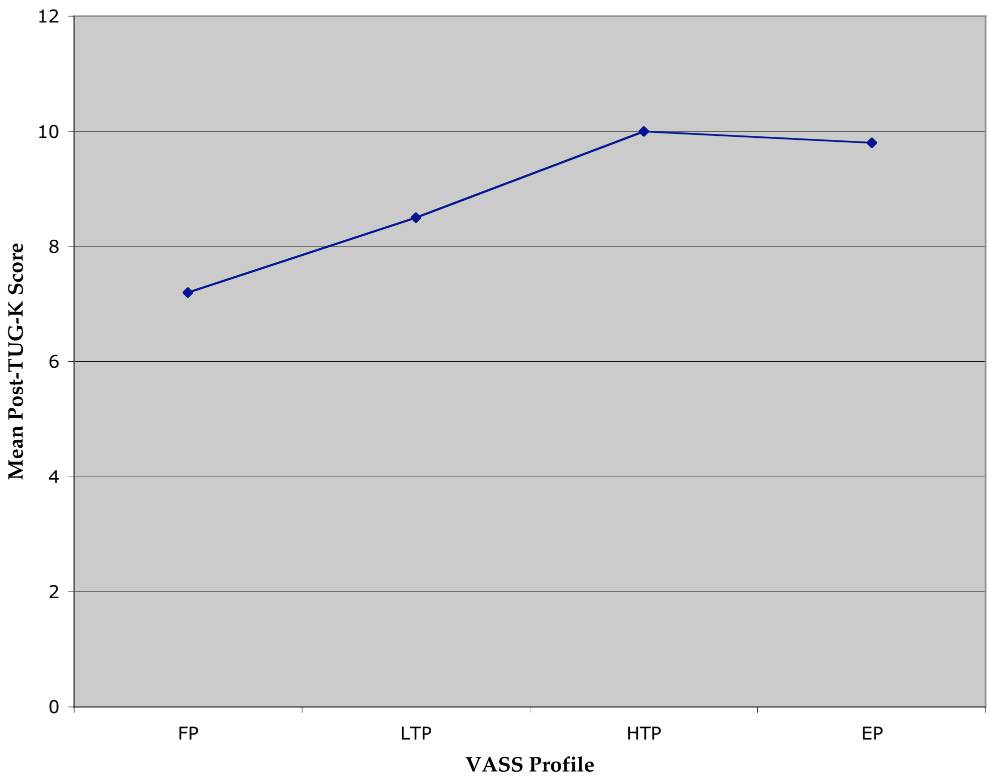

Figure 6.5 Mean Post-TUG-K Score by Post-Unit VASS Profile

Duplicate analyses were performed with achievement and pre- and post-unit VASS profiles dividing the students on basis of group, classroom and online. A summary of these ANCOVA analyses is shown in Table 6.5. With the classroom group, there was not a significant difference on achievement with pre-unit VASS profiles categories, but similar to the whole group, there was a significant difference in relation to the post-unit VASS profile. There was no relationship between the pre- or post-unit VASS profiles categories with respect to achievement for the online group. Figure 6.6 illustrates the differences between the groups of the mean post-TUG-K scores by VASS profile.

Table 6.5

Summary of ANCOVA Results of Post-TUG-K on Pre-TUG-K and Pre- and Post-VASS by Classroom and Online Group

	Classroom Group		Online Group	
	Pre-VASS	Post-VASS	Pre-VASS	Post-VASS
p-value	.42	.04	.54	.56

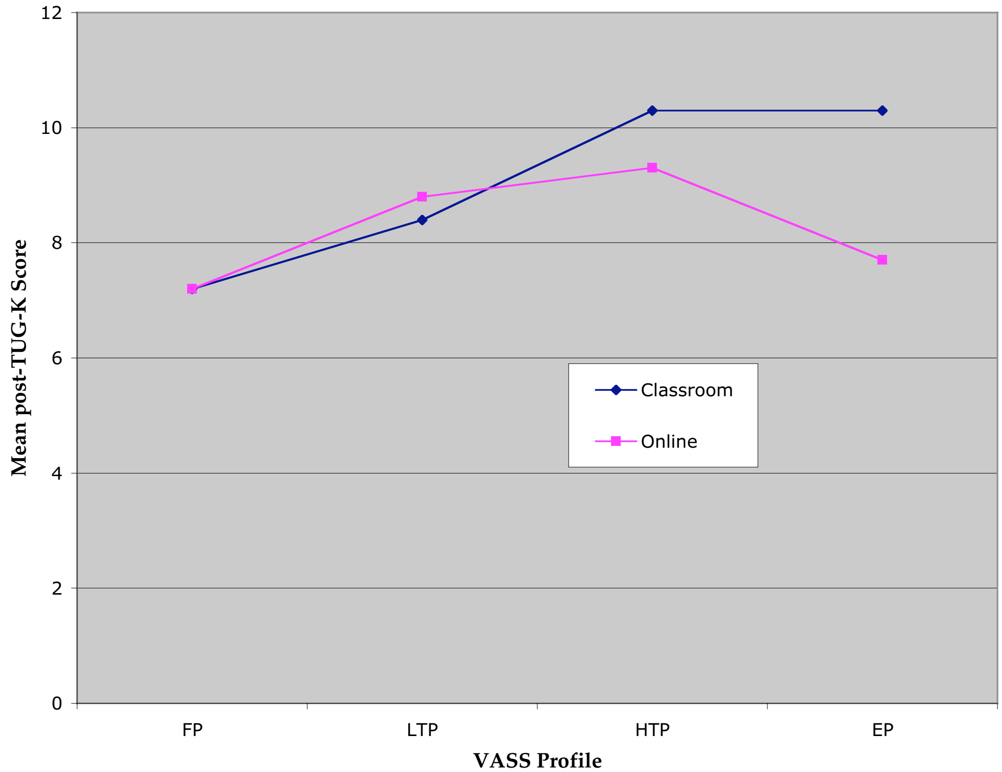

Figure 6.6 Mean Post-TUG-K Score by Post-Unit VASS Profile Both Groups

Discussion

One of the primary purposes of this project was to assess the students' attitudes during this MBL unit. The most direct measure of this was an assessment of their enjoyment of the unit. Students reported a mild, but certainly not overwhelming, enjoyment of the unit. The students who completed the unit in a traditional classroom setting reported a significantly higher level of enjoyment than those students who completed the unit entirely online.

The vast majority of the students felt they had learned 'a little' or more physics over the course of the unit. Comments made by the students on an online bulletin board made it clear some students had difficulty accepting that learning could be taking place in the absence of a textbook, and in the case of the online group, a teacher. Both groups reported, with no significant difference, they perceived this unit as being different from their normal science class experiences.

The most positive responses of the students were in regards to the use of the computer and related MBL technology. Students in both groups reported high enjoying using the technology, despite over half of the students reporting they experienced computer problems. Somewhat surprisingly, the classroom group reported a higher rate of computer problems than the online group.

Collectively, these results indicate that student attitudes toward this unit were positive. Student attitudes were the most positive when dealing with issues related to the technology. Student attitudes were the most negative when measured against aspects of the unit that pushed the students out of their collective comfort zone.

The second purpose of this study was to determine the level of the students' understanding of the nature of science, if their views changed over the course of instruction, and if their views were related to their physics achievement. Not surprisingly, the VASS results indicated that most students held to a folk or low transitional view of science. Students in these categories matched less than half of the responses of experts on the survey statements. There was not a significant difference between the groups, online and classroom, as to their views about physics on either the pre- or post-unit VASS.

For this study, expectations for changes in student attitudes about science were low, given the short duration of this unit. Some studies discussed earlier have indicated that instruction in science actually decreases the level of a students' understanding of the process of science. While this also appeared to be true in this study, statistical tests revealed there was not a significant difference on the VASS profile of the students from pre- to post-unit.

When the students' views about science were compared with science achievement, it was found that the level of sophistication of their views about physics prior to instruction was not related to their achievement. Interestingly, the level of sophistication of their views about physics after instruction was related to achievement. Students who finished the unit with more advanced views of physics tended to have higher achievement scores. This seems to suggest that a student's conceptual understanding of the physics topics and sophistication of their views about physics developed simultaneously.

When achievement and post-unit VASS profiles were compared for each of the groups, online and classroom, only the classroom group displayed a relationship between students' VASS category and achievement. This coupled with the fact that students in the online category displayed a more precipitous decline toward the FP after instruction seem to indicate an important aspect of having a teacher guide conceptual development during a unit. The additional teacher-student interactions could help foster the classroom group's greater understanding of the nature of science and help explain why their achievement in the unit was related to this increased understanding.

In conclusion, this study found that students enjoyed completing MBL units on motion. This was not surprising as students typically report positive attitudes when using technology. A novelty effect likely contributed to this finding as this was a short unit that students believed was different than their normal science instruction. In measuring the student views about physics, the students held moderate to low levels of understanding, and completion of this unit did not seem to affect their level of their understanding. Lastly, since there was correlation between achievement and post-unit VASS profiles, students' conceptual understanding and views about science developed in relation to each other.

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Chapter 7

High School Physics Students' Conceptions of Position, Velocity, and Acceleration during a Computer-based Unit on Kinematics

Introduction

Students typically enroll in physics classes during either their junior or senior year of high school, if at all. Students will therefore undergo around 16-18 years of observation about physical phenomena before they receive extensive formal training about these phenomena. Unfortunately, much of the observation of the natural world by students leads them to formulate incorrect schema about the nature of motion. Hidden from their observation are forces that help define motion according to Newton, whose beliefs are accepted for the motion of most objects. Research has shown that typical physics instruction has generally proven ineffective at rooting out these alternative conceptions (also called preconceptions or misconceptions in the literature) as to the nature of motion. New techniques and new technologies are now available to aid teachers' efforts to change students' conceptions. Before these can be effective, however, one must have a clear picture of the conceptual understanding of students with regards to motion.

Literature Review

In one of early studies on student preconceptions, Clement (1982) videotaped students as they solved problems in mechanics. His analysis showed students often believed that motion implied force. Students would depict a force acting in the direction of the motion regardless of the situation. He determined that the pattern of responses by students was very similar to a Galilean point of view of mechanics. Students were also tested after the completion of a mechanics course, and while there was some improvement in the conceptual understanding of the problems, still less than 20% of the students answered correctly. In 1987, Gunstone attempted to replicate the measures of alternative conceptions produced by Clement. Over 5500 high school students completed an examination after a year of physics instruction. While the results revealed similar misconceptions as first shown by Clement, they were not as drastic. Gunstone hypothesized the differences may have been caused by physics teachers being more aware of the alternative conceptions of students, or that this exam was given in multiple choice format to facilitate a large population.

The other seminal studies on student conceptions in physics were completed by Halloun and Hestenes (1985a; 1985b). The results were reported in a pair of articles detailing the level of student conceptions in mechanics and what alternative conceptions the students held. First, they administered a mechanics test to about a thousand high school and college physics students. They found that pre-instruction high school physics students' levels of understanding were barely above the level of guessing. Post-instruction high school students were able to answer 44-52% of the questions correctly. This was roughly the same level as the pre-test for university physics students, who had taken physics in high school. After instruction, these university physics students averaged 64% correct. To them, this was a very disappointing increase. In fact, Halloun and Hestenes (1985b) noted,

> A low score on the physics diagnostic test does not mean simply that basic concepts of Newtonian mechanics are missing; it means that alternative misconceptions about mechanics are firmly in place. If such misconceptions are not corrected early in the course, the student will not only fail to understand much of the material, but worse, he is likely to dress up his

> misconceptions in scientific jargon, giving the false impression that he has learned something about science. (p. 1048)

Halloun and Hestenes (1985a) went on to examine what alternate conceptions of mechanics were possessed by students. One of the main discoveries was again similar to Clement. Students believed that motion is proportional to force. Acceleration was only associated with an increasing force. They also found that students had very loose and inconsistent definitions of simple concepts such as distance, velocity, and acceleration. Only 17% of the students surveyed, n=478, could be classified as having a primarily Newtonian view of mechanics.

Because the alternative conceptions of mechanics held by students are so prevalent, they have been examined at all ages and stages. In an effort to determine the origin of alternative conceptions Bliss and Ogborn (1994) studied infants. They categorized the stages and observations related to motion as follows; 0-4 months- notice movement, 4-9 months- make effort to move, 9-12 months- move objects and self, 12-18 months- walk/run, and 18+ months- jump, carry and throw. In another study of young children, pre-school and kindergarten students outperformed school aged students on motion concepts, possibly due to the lack of well-formed alternative conceptions (Pine, Messer, & St. John, 2001).

Students in grades 4-9 were found to have a 'straight down' belief system as to how objects would fall (Shemesh & Eckstein, 1993). This was particularly strong for students in the lower grades. In this same age group, over 75% of the students were classified as providing intuitive, correct answers with incorrect reasoning, or logical, incorrect answer but with systematic reasoning, answers to a mechanics scenario (Eckstein & Shemesh, 1989). The percentage of students in these categories remained constant across age levels until students received instruction. A study of fifth grade students revealed that over 90% held misconceptions and no correlation existed between how the teachers ranked the students according to ability and the students' misconceptions (Weller, 1995). Slightly older students, prior to physics instruction, also demonstrated a belief in the influence of shape and weight on the motion of an object (Fischbein, Stavy, & Ma-Naim, 1989).

Other studies of middle and high school aged students found similar patterns of alternative conceptions. A study of seven-sixteen year old students uncovered a difference in the description of motion based on the animation of the object (Whitelock, 1991). If the object was living, students were more likely to believe in impetus theory, and if it was an inanimate object, they were more likely to subscribe to straight down theory. In an examination of ten-seventeen year old students, Marioni (1989) found alternative conceptions based on an absolute frame of reference and, once again, the relationship of force and motion. Research consisting of interviews with twenty-five 11-18 year old students found they also had alternative conceptions related to the support of objects, prevention of motion, and effort to move objects (Bliss, Ogborn, & Whitelock, 1989).

A survey of college-bound high school seniors enrolled in a physics class revealed similar alternative conceptions (Sadanand & Kess, 1990). These students deemed a constant force to require a constant motion and that no force was necessary for inanimate objects to support other objects, but forces were required if animate objects were supporting other objects. Interviews with students revealed alternative conceptions including the personification of inanimate objects (Gilbert, Watts, & Osborne, 1982). These interviews also revealed that students constructed parallel conceptions, one for the classroom and one for the outside world. "The students, therefore, has (sic) views but the learned science viewpoint is not one that is used outside the formal learning situation" (Gilbert et al., 1982, p.64).

Velocity is a concept frequently appearing in the literature with associated alternative conceptions. In a review of literature, McDermott (1984) compiled data showing students had difficulty distinguishing between position and velocity, distinguishing between velocity and the change in velocity, and neglected the time change over which changes in velocity occurred. Another literature review revealed that alternative conceptions in physics were similar in the United States, England, Japan and Israel (Van Hise, 1988).

Another phase of physics education research involves discovering effective ways to correct the alternative conceptions held by students. Some believe as students matured, their conceptual frameworks would become more difficult to modify. A study of Australian year 6 and year 10 students, however, refuted this notion (Palmer & Flanagan, 1997). In this study, both age levels showed similar amounts of conceptual change after intervention. One intervention that was studied to bring about conceptual change was deductive reasoning (Park & Han, 2002). This method was only shown to be effective if the interviewer assisted the students in removing a series of roadblocks, such as not reading or using the premises and rejecting logical conclusions.

A more common and effective method to induce conceptual change is through the use of refutational texts (Guzzetti, 2000; Hynd, McWhorter, Phares, & Suttles, 1994). These texts confront student ideas, present scenarios where these ideas will no longer explain the phenomena, and then present accepted explanations and concepts. Use of these texts is only effective when combined with teacher-led discussions. If students are allowed un-moderated discussions, dominant students can reinforce alternative conceptions. In an examination of four different methods to realize conceptual change in physics, Eryilmaz (2002) concluded that such teacher-led discussions provided both a decrease in alternative conceptions as well as an increase in the understanding of correct conceptions.

A variety of methods using computers in the classroom to achieve conceptual change have been studied. In one case, students were given a game-like simulation to learn mechanics concepts (Flick, 1990). Unfortunately, students' gaming skills were higher than their level of understanding, as they were able to solve the game without demonstrating conceptual change. In other cases, computer programs have been specifically designed to confront and remediate students' alternative conceptions in mechanics (Tao, 1997; Tao & Gunstone, 1999). While these have proven to be effective, they have also shown that students' new scientific conceptions are often context dependant (Tao & Gunstone, 1999). Students will apply their correct new conceptions to the computer or in the classroom, but have difficulties applying these correct conceptions to real world scenarios.

Specific computer interventions using prediction to understand one dimensional motion (Monaghan & Clement, 1999) and using remediation to clear confusion between position and velocity (Zietsman & Hewson, 1986) haven proven effective at achieving conceptual change, but are time intensive. One of the methods to harness the capabilities of computer remediation is to use the computer to first assess a student's alternative conceptions and then present remediation directly related to the individual needs of the student (Hewson, 1984; Pek & Poh, 2000). Hewson (1984) states, "The ability of the microcomputer to allow a student to interact actively with instructional material and to follow an individualized path at his or her own pace is very useful in designing instruction…" (p. 17).

In analysis of tasks and interviews Trowbridge and McDermott specifically assessed college students' conceptions of velocity (1980) and acceleration (1981) in one dimension. With regards to velocity, they discovered that nearly every error by students related to confusing velocity and position. They also found after instruction students were much more capable of completing the task correctly, as nearly 70% of the students demonstrated success after instruction. Acceleration, however, was a much more difficult concept for students to master. Students confused acceleration with position, and more often with velocity. Students would also examine the change in velocity, but with no regards to the change in time. After instruction the majority of students still held these alternative conceptions. Similarly, in assessing high school honors physics students after instruction, Peters (1982) determined that only 30% of the students accurately described a velocity-time event in one dimension and this dropped to 10% for an event in two dimensions.

Research Questions

This research project aimed to assess the conceptual understanding of high school physics students with regards to position-time, velocity-time, and acceleration-time graphs. The conceptual understandings of the students were measured both before and after a short, two to four week, treatment period. The second goal of this project was to assess if the students achieved any conceptual gains due to the treatment. The students were in two groups with regards to how the treatment was delivered. One group received the treatment in a normal classroom setting, and the other group received the treatment online. The last focus of this study was to determine if there was a difference in the conceptions or the conceptual gains between the students in the two groups.

Population

This study was completed with 150 high school physics students from five different high schools in North Carolina. The high schools were from a variety of geographic and demographic regions of the state. For all but four of the participants, this was the first physics class they had taken. All of the instruction for this unit took place within the first two months of the school year. This was the first instruction that the students had received on motion.

The group of students who completed the instruction in a traditional classroom setting was from three high schools and had 95 members. They were 60% male, 78% Caucasian, and 13% African-American. Their ages ranged from 15-18 and all but one student were either juniors or seniors in high school.

The group of students who completed the instruction in an online environment was from two high schools and had 55 members. They were 50% male, 75% African-American, and 8% Caucasian. Their ages ranged from 15-18 and they were all either juniors or seniors in high school.

Method

The curriculum used for this research project was the Tools for Scientific Thinking- Motion (TST) curriculum developed by Sokoloff and Thornton (1998). This is microcomputer-based laboratory (MBL) curriculum. The students move themselves and carts in front of motion detectors and display, in real-time, graphs of the motion on the computer screen. Beichner (1990) showed the kinesthetic portion of this type of lab was critical to students gaining understanding. Thornton (1986) first experimented with creating curriculum using the motion detectors with sixth grade students. He was quick to realize this style of curriculum could be applied to physics learners with naïve concepts at any age. When the curriculum was further developed and used with non-physics major college students, these students were able to perform equally well on a series of motion graphing questions as were physics majors who had also completed the material in a traditional physics course.

Thornton (1987) felt MBL activities, when properly used in the classroom, could provide numerous pedagogical advantages. The MBL activities encourage inquiry and allow students to easily engage in the scientific process, as the computer handles the drudgery of the data collection. The technology aptitude necessary for MBL activities is easily mastered and can be readily applied to extension investigations that student find personally interesting. Thornton (1986) concluded,

> …it would seem that MBL is effective for teaching science to students with a wide range of abilities and ages. MBL gives students an opportunity to investigate their "common sense" understandings of science. When MBL proves are well designed with good user interfaces and used properly as tools to aid scientific thinking, microcomputer-based laboratories can be a powerful adjunct to science instruction.

The first six investigations of the TST curriculum were given to all 150 students in the project. Ninety-five of the students completed the investigations in a normal classroom setting. They were given paper copies of the activities and worked in groups of two to four students at laptop computers with motion detectors. The teachers in these classrooms were available to assist the students with misconceptions and difficulties they might encounter.

The online students, n= 55, also completed the same six activities in groups of two to four students with computers and motion detectors. These students, however, were not given paper copies of the activities or given assistance from their classroom teachers. These students were directed to a website designed by the researcher that presented the same investigations and completed the activities entirely in an online environment. When these students answered questions, the answers were emailed to the researcher who graded them and returned scores back to their classroom teachers. The only time these students used papers was in instances where they were directed by the website to print graph axis so they could make predictions. The teachers in these classrooms were asked not to assist in concept development. The students were to gain understanding from peer interactions, the investigations, the website, and its related links.

Instrument

The instrument used to assess the conceptual understanding of the students was the Test for Understanding Graphics- Kinematics (TUG-K- see Appendix A) by Beichner (1998). This test was originally developed to investigate the importance of the kinesthetic aspect of MBL activities (Beichner, 1990). The TUG-K was further refined to be an instrument for generically testing MBL activities in kinematics (Beichner, 1994). The KR-20 reliability statistic for the TUG-K was .83, well above the .70 required for a reliable test. The Point-Biserial Coefficient of .74, was well above the .20 required for reliable items. Fifteen science educators established the validity. The test contains 21 multiple-choice questions to test seven objectives (see Table 7.1). The final version of the test was given to over 500 high school and college students after instruction on kinematics.

Table 7.1

Objectives of TUG-K*

Given:	The student will:
1. Position-time graph	Determine Velocity
2. Velocity-time graph	Determine Acceleration
3. Velocity-time graph	Determine Displacement
4. Acceleration-time graph	Determine Change in Velocity
5. A Kinematics Graph	Select Another Corresponding Graph
6. A Kinematics Graph	Select Textual Description
7. Textual Motion Description	Select Corresponding Graph

*(Beichner, 1994)

Results

To assess the conceptual level of the students in this project, the pre- and post-test scores on the TUG-K in this project were compared with Beichner's results (see Table 7.2). In this and subsequent comparisons, 'all' represents the entire student population of the project, 'classroom' is the group that completed the activities in a normal classroom setting, and 'online' represents the group that completed the activities online. This table shows students in the present study were at similar conceptual levels as the combination of high school and college students tested by Beichner. There is a significant difference, $p = .01$, between the online and classroom groups' post-test which may suggest the classroom group has a slightly higher conceptual understanding. The classroom group, however, also started at a significantly, $p < .001$, higher level.

Table 7.2

Comparisons of Means on the TUG-K

	Pre-test Mean (SD)	Post-test Mean (SD)	p-value for Post-test*
Beichner	n/a	8.5 (4.6)	
All	4.9 (3.5)	8.8 (4.2)	.45
Classroom	5.9 (3.8)	9.4 (4.3)	.06
Online	3.3 (2.2)	7.6 (3.8)	.10

*p-value from t-test with Beichner

To inspect the student responses in greater detail, the seven objectives of the TUG-K can also be examined (see Figure 7.1). To calculate the percentages given in the table, all the correct responses on each question for an objective were divided by the total number of responses to the questions for that objective. Once again, there appears to be a great deal of similarity between the students in this project and those tested by Beichner. The range of correct responses on the seven objectives for Beichner was 23-51%, and for the students in this project, it was a nearly identical 21-53%. For both Beichner and this project, the objective with the highest rate of correct responses was objective one, to determine velocity given a position-time graph. The most difficult objective was objective 4, to determine the change in velocity given an acceleration-time graph.

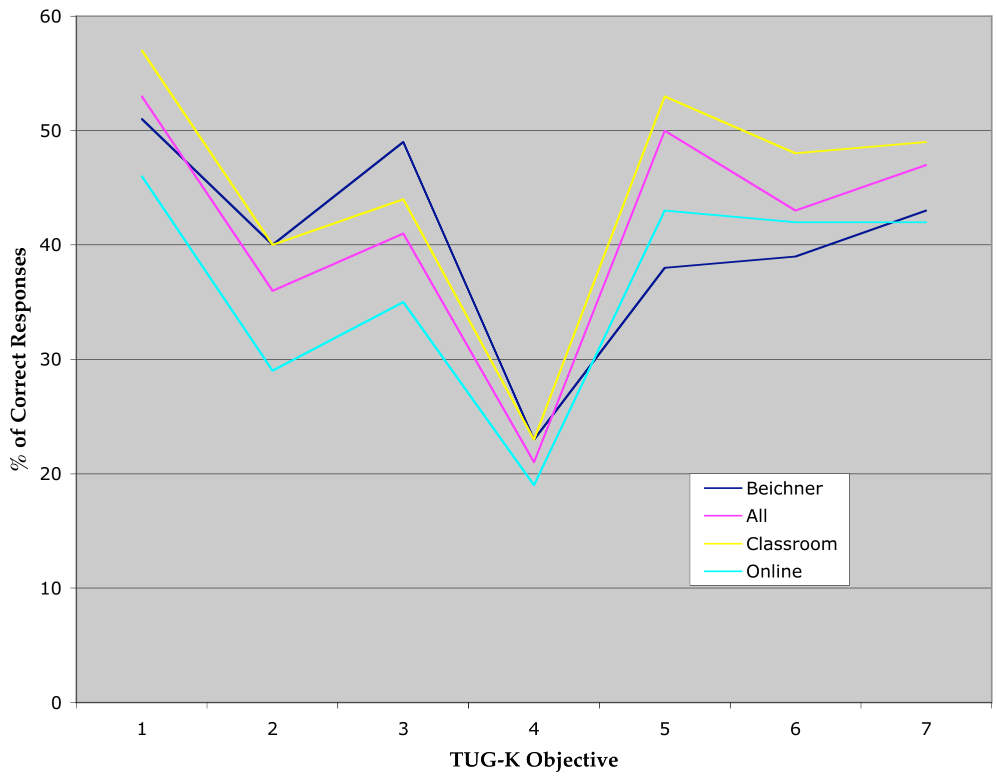

Figure 7.1 Comparison of Post-Test Achievement on TUG-K Objectives (% correct)

One more level of comparisons can be made, and that is to compare the responses on a per item basis (see table 7.3). Once again, the trends between the students in this project and those in Beichner's are quite similar. On only five items was there a difference of 10% or more between the whole groups. On items 1, 8, 14, and 15, students on this project scored higher, and on item 16 students in Beichner's groups scored higher.

Table 7.3
Comparison on Achievement on TUG-K items (as % correct)

Objective	Item	Beichner	All	Classroom	Online
1	5	73	76	80	68
1	13	61	63	62	64
1	17	21	20	27	6
2	2	63	60	67	47
2	6	25	16	19	12
2	7	31	33	35	28
3	4	28	21	24	16
3	18	46	41	45	34
3	20	72	61	64	56
4	1	16	29	33	20
4	10	30	27	25	30
4	16	22	9	10	6
5	11	36	45	49	38
5	14	48	64	68	56
5	15	29	39	42	35
6	3	62	60	63	55
6	8	37	53	55	48
6	21	18	24	25	22
7	9	24	31	33	28
7	12	67	71	76	62
7	19	37	38	40	35

Given the similarity at all levels of examination between the students in this study and those that participated in establishing the baseline data for the TUG-K, it seems likely students in this study share the same six difficulties that Beichner (1994) identified. These difficulties are: 1) graph as picture errors, 2) slope/height confusion, 3) variable confusion, 4) non-origin slope errors, 5) area ignorance, and 6) area/slope/height confusion.

Discussion

The mean scores on the pre- and post-TUG-K test for students in this project suggest many alternative conceptions still exist. The pre-test scores were essentially at the level of random guessing; suggesting students' understanding of these graphs was woefully inadequate at the beginning of the unit. While the scores increased significantly after instruction, given the research in kinematics that shows how difficult it is to change students' alternative conceptions, it is not surprising the scores remain relatively low. In fact, in a similar study, Eryilmaz (2002) designed an 18 item post-test and the mean score was between four and five.

In trying to examine what alternative and correct conceptions the students held after the unit, the achievement on the TUG-K can be furthered examined by objective and item. Students were most successful on the objective stating, given a position-time graph determine velocity. Even this objective, however, is somewhat ambiguous when examined at the item level. One of the items under this objective was question five. This was the highest scoring question on the test. Students were asked to find the velocity at two seconds from a distance-time graph that depicted a constant velocity that rose from the origin. Students could correctly solve for the slope and find the correct answer, however, they could also make the common mistake of confusing position and velocity. In this case, students would divide the position at the given two second mark, divide by two, and also arrive at the correct answer. Item 17 also tested objective one. This question was the third lowest scoring item on the exam. These questions asked essentially the same thing, to solve for the velocity at a given time on a distance-time graph. This graph, however, was irregular in shape and had a negative slope through the time referred to in the question. Confusing position for velocity on this question would not result in the correct response. If this was the mistake that was occurring students would select choice B. In fact, 46% of the students in both the classroom and the online group selected that choice, the most frequent answer for both groups.

A sampling of some of the responses that were emailed to the researcher as part of the work to complete the investigations online reveals some of the same ambiguity. Some students' answers showed clear understanding of the concept that the slope on the distance-time graph depicted velocity. A sample student response illustrates this, "The quicker you move the faster you cover distance so the graph whold (sic) have a larger slope. The slower you move the more horizontal the line would be in the graph so the slope would be smaller." A common alternative suggestion involved the 'wavy-ness' of the lines. This was created by the students' steps as they walked in front of the motion detector. Students related the frequency of these waves with velocity, "If I moved faster there would be more curves in the graph or the graph would go up and down more. If I moved slower the the (sic) graph would have less curves or go up and down less." Another group stated, "if it is faster then the curves in the lines a much shorter than those of if you were walking slower. When walking slower the curve is more strectched (sic) out".

The objective, given a kinematics graph select another corresponding graph, had the second highest frequency of correct responses. The three items, numbers 11, 14, and 15, for this object asked the students to choose the corresponding velocity-time for a displacement-time, acceleration-time for a velocity-time, and velocity-time for an acceleration-time graph respectively. There was much less ambiguity about the achievement of the students on this objective. For all three questions, the students scored between 39-64%. This is a skill that is practiced repeatedly throughout the TST curriculum. Somewhat surprisingly, the highest scoring question was not the item where the corresponding displacement-time graph was chosen for a given velocity-time graph, but was instead when the corresponding velocity-time graph was chosen for given acceleration-time graph. A closer inspection of the questions reveals that for the velocity-time graph answers, there are two graphs with the correct shape. To answer the question correctly, judgment must also be made as to the magnitude of the velocity depicted on the given displacement-time graph.

The objective, given an acceleration-time graph determine the change in velocity, produced by far the lowest achievement of the students in this project. While not more that 30% of the students answered any of the three questions for this objective correctly, item 16 was by far the lowest scoring item on the test. In this item the students were given an acceleration-time graph and asked to calculate the change in velocity over the first three seconds. On this item, students overwhelmingly committed what Beichner called area/slope/height confusion. Instead of calculating the area under the curve, 45% of the students calculated the slope, and 35% of the students reported the height of the graph at that point as the correct answer. Responses from the online group indicate that some students seem to understand the relationship of acceleration-time and velocity-time graphs, "if the velocity slopes down then the acceleration is negative. If the velocity slope is posive (sic) then the acceleration is positive." Other groups had a more mixed signal, while being able to recite definitions but not understand all the possibilities, "If the velocity is increasing so is the acceleration and if the velocity is decreasing so is the acceleration because acceleration equals the change of velocity over the change of time." Still other groups appeared to be more totally confused, "Yes the acceleration and the velocity did agree because they started off medium fast and then slowed to a complete stop. The sign can be represented by the sign of the velocity, if the velocity is positive then the acceleration will also be positive." As the students progressed through acceleration section of the activities, the quality of work received began to decline. It is possible students began to tire of the unit and had to expend considerably more effort to understand the concepts. Moving from an acceleration-time graph to understanding the change in velocity of the object is not a skill emphasized in the TST curriculum.

Much has been said about the comparison between students in this project and Beichner's research but little mention has been made about difference between the two groups for this project, the classroom and online groups. In examining the data there is quite nearly a mirror effect, as the largest and smallest percentages of correct answers are the same by object, and nearly so by item. Most of the differences between these two groups can be traced to the level of initial understanding demonstrated by the classroom group. This group started at a higher level and at the end of instruction was able to gain the same amount as the online group, thereby retaining an edge in the level of understanding.

Two items stand out for consideration, two and seventeen, as there is a greater than 20% increase by the classroom group over the online group. At first glance there appears to be little in common between the questions, item two addresses objective two, and item 17 addresses objective 1. The only commonality in the questions, which may or may not be related to the differences in scores, is that for the part of the graph in question, the slope is negative. As to whether it is more difficult to comprehend negative slopes and their meaning in an online environment would call for additional study.

In conclusion, students completing this unit were able to make conceptual gains as illustrated by their TUG-K scores. Inspection of these tests, however, reveals that even post-instruction the students retain several of the entrenched alternative conceptions about motion that are prevalent in the literature. The students display confusion selecting the correct variables, displacement, velocity, or acceleration, as well as confusion as to which operation to treat the graph with, determining height, slope or area under the curve. While MBL units have proven here and in other studies to be effective at inducing conceptual change, there is still difficulty in changing students alternative conceptions about motion to levels that would be considered educational success, students 'passing' the assessment. This calls for more research on MBL's, both in the classroom and online, in combination with other methods of conceptual change, such as refutational texts, and for longer durations.

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Appendix A

Test of Understanding Graphics- Kinematics

(TUG-K)

Test of Understanding Graphs– Kinematics

version 2.6

Instructions

Wait until you are told to begin, then turn to the next page and begin working. Answer each question as accurately as you can. There is only one correct answer for each item. Feel free to use a calculator and scratch paper if you wish.

Use a #2 pencil to **record your answers** on the computer sheet, but **please do not write in the test booklet.**

You will have approximately one hour to complete the test. If you finish early, check over your work before handing in both the answer sheet and the test booklet.

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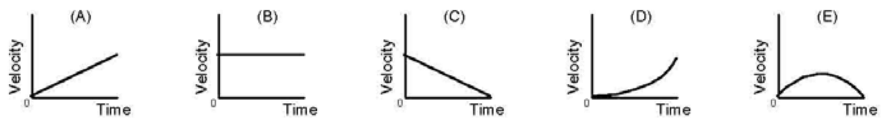
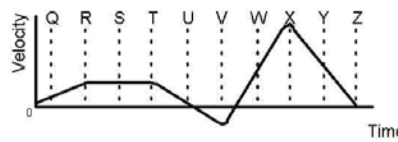
1. Velocity versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest change in position during the interval?



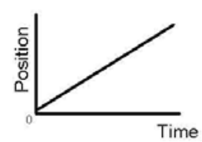
2. When is the acceleration most negative?

(A) R to T
(B) T to V
(C) V
(D) X
(E) X to Z



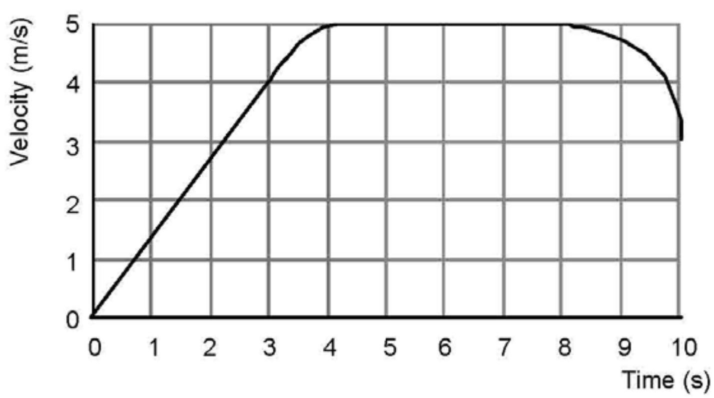
3. To the right is a graph of an object's motion. Which sentence is the best interpretation?

(A) The object is moving with a constant, non-zero acceleration.
(B) The object does not move.
(C) The object is moving with a uniformly increasing velocity.
(D) The object is moving with a constant velocity.
(E) The object is moving with a uniformly increasing acceleration.



4. An elevator moves from the basement to the tenth floor of a building. The mass of the elevator is 1000 kg and it moves as shown in the velocity-time graph below. How far does it move during the first three seconds of motion?

(A) 0.75 m
(B) 1.33 m
(C) 4.0 m
(D) 6.0 m
(E) 12.0 m

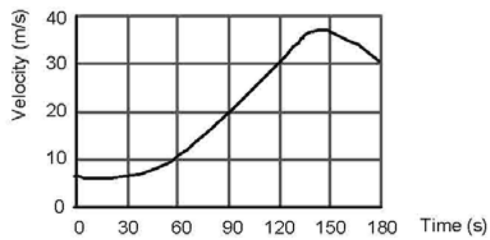


5. The velocity at the 2 second point is:

(A) 0.4 m/s
(B) 2.0 m/s
(C) 2.5 m/s
(D) 5.0 m/s
(E) 10.0 m/s

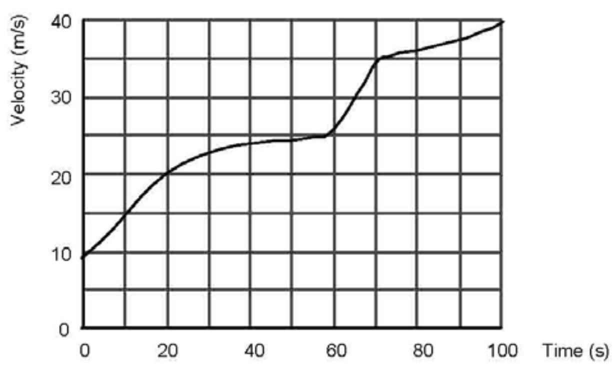
6. This graph shows velocity as a function of time for a car of mass 1.5×10^3 kg. What was the acceleration at the 90 s mark?

(A) $0.22\ m/s^2$
(B) $0.33\ m/s^2$
(C) $1.0\ m/s^2$
(D) $9.8\ m/s^2$
(E) $20\ m/s^2$

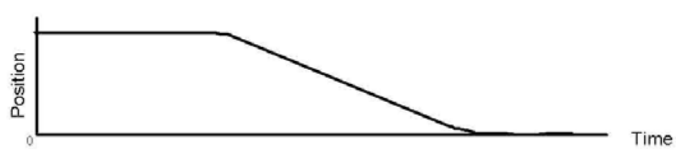


7. The motion of an object traveling in a straight line is represented by the following graph. At time = 65 s, the magnitude of the instantaneous acceleration of the object was most nearly:

(A) $1\ m/s^2$
(B) $2\ m/s^2$
(C) $+9.8\ m/s^2$
(D) $+30\ m/s^2$
(E) $+34\ m/s^2$

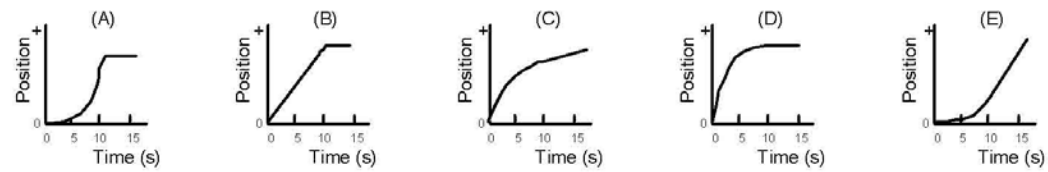


8. Here is a graph of an object's motion. Which sentence is a correct interpretation?

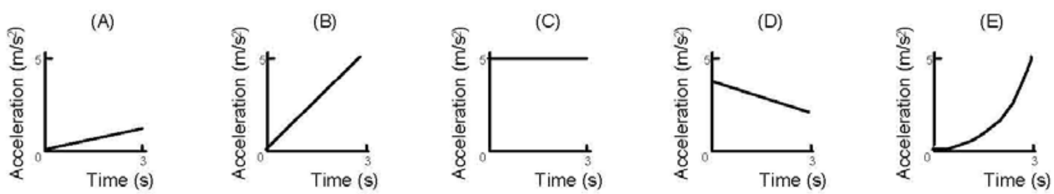


(A) The object rolls along a flat surface. Then it rolls forward down a hill, and then finally stops.
(B) The object doesn't move at first. Then it rolls forward down a hill and finally stops.
(C) The object is moving at constant velocity. Then it slows down and stops.
(D) The object doesn't move at first. Then it moves backwards and then finally stops
(E) The object moves along a flat area, moves backwards down a hill, and then it keeps moving.

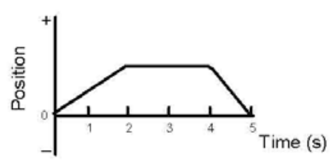
9. An object starts from rest and undergoes a positive, constant acceleration for ten seconds. It then continues on with a constant velocity. Which of the following graphs correctly describes this situation?



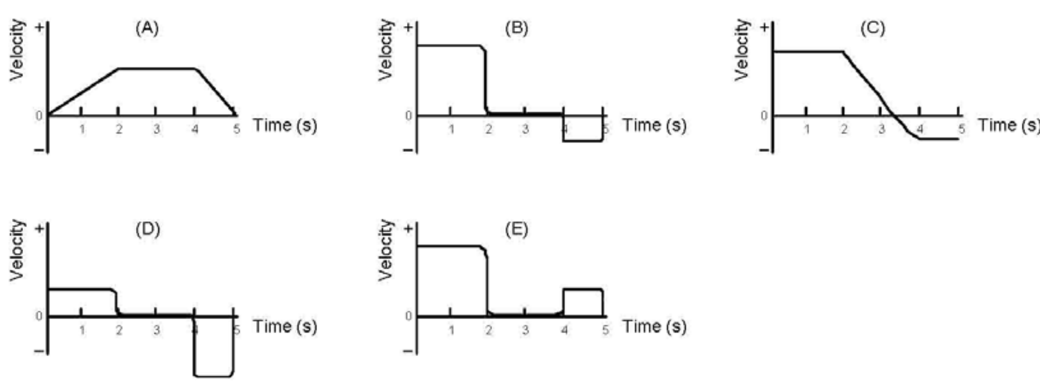
10. Five objects move according to the following acceleration versus time graphs. Which has the smallest change in velocity during the three second interval?



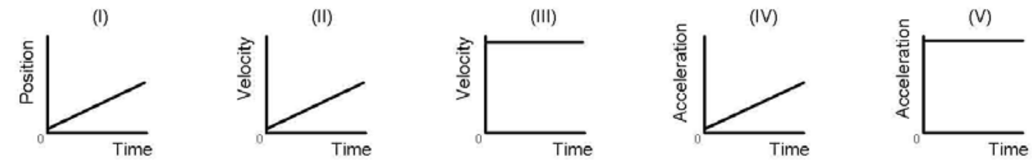
11. The following is a position-time graph for an object during a 5 s time interval.



Which one of the following graphs of velocity versus time would best represent the object's motion during the same time interval?



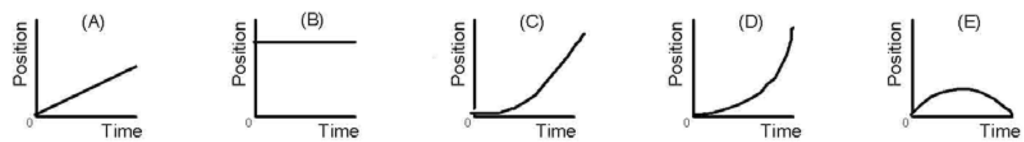
12. Consider the following graphs, noting the different axes:



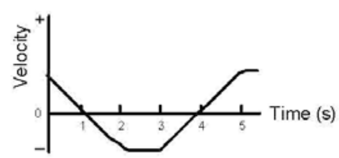
Which of these represent(s) motion at constant velocity?

(A) I, II, and IV
(B) I and III
(C) II and V
(D) IV only
(E) V only

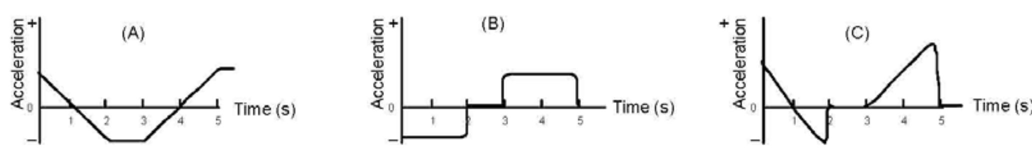
13. Position versus time graphs for five objects are shown below. All axes have the same scale. Which object had the highest instantaneous velocity during the interval?

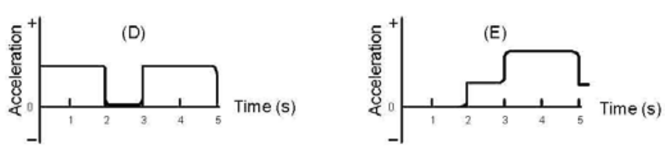


14. The following represents a velocity-time graph for an object during a 5 s time interval.

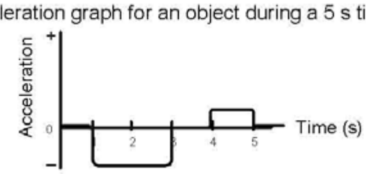


Which one of the following graphs of acceleration versus time would best represent the object's motion during the same time interval?

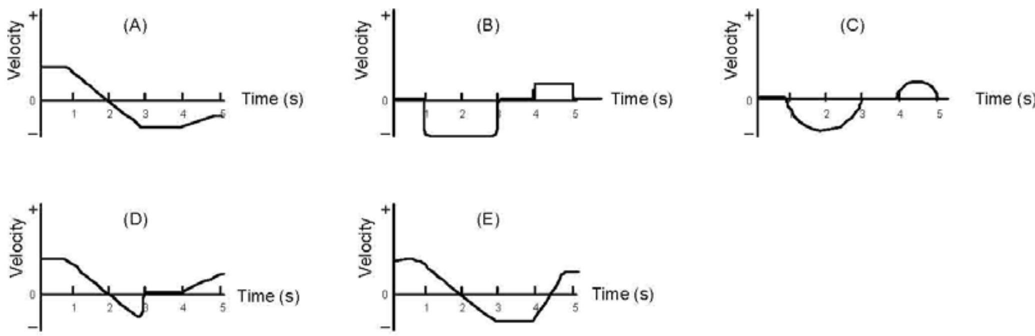




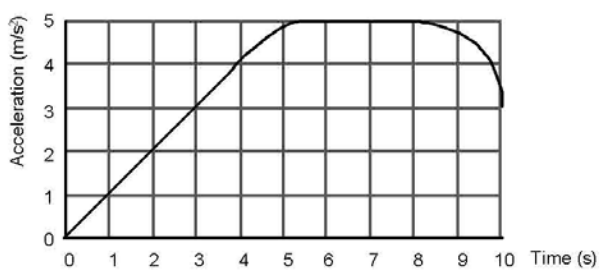
15. The following represents an acceleration graph for an object during a 5 s time interval.



Which one of the following graphs of velocity versus time would best represent the object's motion during the same time interval?



16. An object moves according to the graph below:

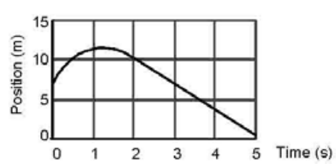


The object's change in velocity during the first three seconds of motion was:

(A) 0.66 m/s (B) 1.0 m/s (C) 3.0 m/s (D) 4.5 m/s (E) 9.8 m/s

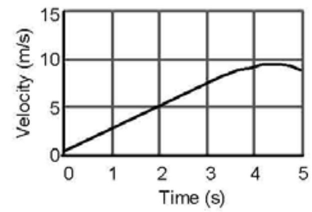
17. The velocity at the 3 second point is about:

(A) -3.3 m/s
(B) -2.0 m/s
(C) -.67 m/s
(D) 5.0 m/s
(E) 7.0 m/s

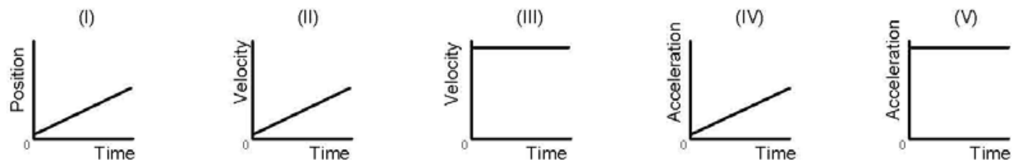


18. If you wanted to know the distance covered during the interval from t = 0 s to t = 2 s, from the graph below you would:

(A) read 5 directly off the vertical axis
(B) find the area between that line segment and the time axis by calculating (5 x 2)/2
(C) find the slope of that line segment by dividing 5 by 2.
(D) find the slope of that line segment by dividing 15 by 5.
(E) Not enough information to answer.



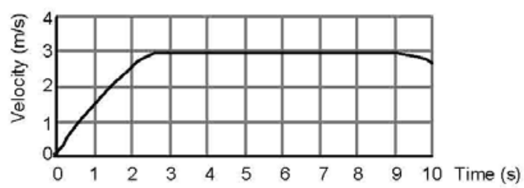
19. Consider the following graphs, noting the different axes:



Which of these represent(s) motion at constant, non-zero acceleration?

(A) I, II, and IV
(B) I and III
(C) II and V
(D) IV only
(E) V only

20. An object moves according to the graph below:



How far does it move during the interval from t = 4 s to t = 8 s?

(A) 0.75 m (B) 3.0 m (C) 4.0 m (D) 8.0 m (E) 12.0 m

21. To the right is a graph of an object's motion. Which sentence is the best interpretation?

(A) The object is moving with a constant acceleration
(B) The object is moving with a uniformly decreasing acceleration.
(C) The object is moving with a uniformly increasing velocity.
(D) The object is moving at a constant velocity.
(E) The object does not move.

Answers:

1.	B
2.	E
3.	D
4.	D
5.	C
6.	B
7.	A
8.	D
9.	E
10.	A
11.	D
12.	B
13.	D
14.	B
15.	A
16.	D
17.	A
18.	B
19.	C
20.	E
21.	A

Appendix B

Views About Science Survey- Physics

(VASS)

Views About Sciences Survey

Form P12

This survey is designed by the Modeling Instruction research team at Arizona State University. It is intended to identify factors that affect people's understanding of physics, and to assist in the design of instructional material.

*Your participation is **voluntary**. The results will not affect your grade, even if you choose not to participate. All data are **confidential.** Your identity will not be disclosed to any party. Return of the survey materials will be considered your consent to participate.*

If you have any question about this survey, please call Dr. I. Halloun at (602) 965-8528.

Please:

*Do **not** write anything on this questionnaire.*
Mark your answers on the computer sheet.
*Use a **No. 2 pencil** only, and follow marking instructions on the computer sheet.*
*Make **only one** mark per item.*
*Do **not** skip any question.*
*Avoid guessing. Your answers should reflect what **you** actually and honestly think.*
Plan to finish the survey in 30 minutes.

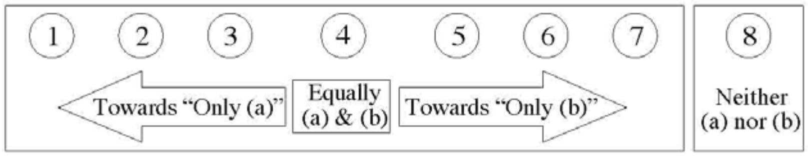
The example below illustrates the eight choices that you have for answering the following 31 questions. Please mark your answers to these questions in section III of the VASS Answer Sheet.

Example

Learning physics requires:
(a) a serious effort.
(b) a special talent.

What would each one of the eight choices mean?

① Only (a), Never (b):	Learning physics requires ***only** a serious effort* and **no** special talent ***at all***.
② Mostly (a), Rarely (b):	Learning physics requires ***far more** a serious effort* than a special talent.
③ More (a) Than (b):	Learning physics requires ***somewhat more** a serious effort* than a special talent.
④ Equally (a) & (b):	Learning physics ***equally*** requires ***both*** a serious effort and a special talent.
⑤ More (b) Than (a):	Learning physics requires ***somewhat more** a special talent* than a serious effort.
⑥ Mostly (b), Rarely (a):	Learning physics requires ***far more*** a *special talent* than a serious effort.
⑦ Only (b), Never (a):	Learning physics requires ***only*** a *special talent* and **no** serious effort ***at all***.
⑧ Neither (a) Nor (b):	Learning physics requires ***neither*** a *special talent* ***nor*** *a serious effort*.



1. Learning physics requires:
   (a) a serious effort.
   (b) a special talent.

2. If I had a choice:
   (a) I would never take any physics course.
   (b) I would still take physics for my own benefit.

3. Reasoning skills that are taught in physics courses can be helpful to me:
   (a) in my everyday life.
   (b) if I were to become a scientist.

4. I study physics:
   (a) to satisfy course requirements.
   (b) to learn useful knowledge.

5. My score on physics exams is a measure of how well:
   (a) I understand the covered material.
   (b) I can do things the way they are done by the teacher or in some course materials.

6. For me, doing well in physics courses depends on:
   (a) how much effort I put into studying.
   (b) how well the teacher explains things in class.

7. When I experience a difficulty while studying physics:
   (a) I immediately seek help, or give up trying.
   (b) I try hard to figure it out on my own.

8. When studying physics in a textbook or in course materials:
   (a) I find the important information and memorize it the way it is presented.
   (b) I organize the material in my own way so that I can understand it.

9. For me, the relationship of physics courses to everyday life is usually:
   (a) easy to recognize.
   (b) hard to recognize.

10. In physics, it is important for me to:
    (a) memorize technical terms and mathematical formulas.
    (b) learn ways to organize information and use it.

1	2	3	4	5	6	7	8
← Towards "Only (a)"			Equally (a) & (b)	Towards "Only (b)" →			Neither (a) nor (b)

11. In physics, mathematical formulas:
    (a) express meaningful relationships among variables.
    (b) provide ways to get numerical answers to problems.

12. After I go through a physics text or course materials and feel that I understand them:
    (a) I can solve related problems on my own.
    (b) I have difficulty solving related problems.

13. The first thing I do when solving a physics problem is:
    (a) represent the situation with sketches and drawings.
    (b) search for formulas that relate givens to unknowns.

14. In order to solve a physics problem, I need to:
    (a) have seen the solution to a similar problem before.
    (b) know how to apply general problem solving techniques.

15. For me, solving a physics problem more than one way:
    (a) is a waste of time.
    (b) helps develop my reasoning skills.

16. After I have answered all questions in a homework physics problem:
    (a) I stop working on the problem.
    (b) I check my answers and the way I obtained them.

17. After the teacher solves a physics problem for which I got a wrong solution:
    (a) I discard my solution and learn the one presented by the teacher.
    (b) I try to figure out how the teacher's solution differs from mine.

18. How well I do on physics exams depends on how well I can:
    (a) recall material in the way it was presented in class.
    (b) solve problems that are somewhat different from ones I have seen before.

19. To me, physics is important as a source of:
    (a) factual information about the natural world.
    (b) ways of thinking about the natural world.

20. As they are currently used, Newton's laws of motion:
    (a) are the same throughout the universe.
    (b) change depending on where you are in the universe.

1	2	3	4	5	6	7	8
Towards "Only (a)"			Equally (a) & (b)	Towards "Only (b)"			Neither (a) nor (b)

21. The laws of physics are:
    (a) inherent in the nature of things and independent of how humans think.
    (b) invented by physicists to organize their knowledge about the natural world.

22. The laws of physics portray the real world:
    (a) exactly the way it is.
    (b) by approximation.

23. Physicists say that electrons and protons exist in an atom because:
    (a) they have seen these particles in their actual form with some instruments.
    (b) they have made observations that can be explained by such particles.

24. Where they are currently used, Newton's laws of motion:
    (a) will always be used as they are.
    (b) could eventually be replaced by other laws.

25. Physicists' current ideas about the particles making up the atom:
    (a) will always be maintained as they are.
    (b) could eventually be replaced by other ideas.

26. If we want to apply a method used for solving one physics problem to another problem, the objects involved in the two problems must be:
    (a) identical in all respects.
    (b) similar in some respects.

27. Different branches of physics, like mechanics and electricity:
    (a) are interrelated by common principles.
    (b) are separate and independent of each other.

28. Physicists use mathematics as:
    (a) a tool for analyzing and communicating their ideas.
    (b) a source of factual knowledge about the natural world.

29. Scientific findings about the natural world are:
    (a) dependent on current scientific knowledge.
    (b) accidental, depending on scientists' luck.

30. Knowledge in chemistry is:
    (a) related to knowledge in physics.
    (b) independent of knowledge in physics.

31. I answered all the questions in this survey:
    (a) to the best of my ability.
    (b) without thinking seriously about them.

Appendix C

Fysics is Fun Pre-Unit Survey

Fysics Is Fun!

Pre-Unit Survey Part I

UserName____Age_______________

Gender_______________________Race___________________________________

Year in School_____________________________________

For the following, please circle your answer.

Do you have a computer at home? Yes No

If yes, does it have Internet access? Yes No

Have you ever taken an online class? Yes No

Which most closely describes how often you use the Internet?

Once a month Twice a month Once a week

Two/Three times a Week Once a day

What is your comfort level with a computer? (One being it hates you and you hate it, and 10 being you carry it with you at all times.)

1 2 3 4 5 6 7 8 9 10

Is this your first physics class? Yes No

Did you take physical Science? Yes No

Did you take Chemistry? Yes No

Are you currently enrolled in a math class? Yes No

If yes, what math class are you currently in? _________________________

What math class do you complete last year? ______________________________

Appendix D

Fysics Is Fun Post-Unit Surveys

Fysics Is Fun!

Post-Unit Survey Part I

UserName____

School____

Please Circle your answer or Write what you think.

Do you think that you learned a lot of physics from this unit?

Not Much A Little Quite a Bit A Lot

What part did you learn the most from? ______________________

____

Did you enjoy this unit? (Not at all) 1 2 3 4 5 (It was great!)

What was your favorite part? ___________________________

Did you like using the computer for the activities? Yes No

What was the best part of using the computer? ________________

____

Did you have computer problems? Yes No

If yes, what problems did you have? _______________________

____

Was this unit different from what you have done in your science classes before?

About the Same Somewhat Different A Lot Different

How was it different? ______________________________

____

On a scale of 1-10, with 1 being low and 10 being high, what overall rating would you give this unit? ________

Fysics Is Fun! **Post-Unit Survey Part I**

UserName____

School____

Please Circle your answer or Write what you think.

Do you think that you learned a lot of physics from this unit?

Not Much   A Little   Quite a Bit   A Lot

What part did you learn the most from? ___________________________

____

Did you enjoy this unit?   (Not at all) 1 2 3 4 5 (It was great!)

What was your favorite part? _____________________________

Did you like using the computer for the activities?   Yes   No

What was the best part of using the computer? ____________________

____

Did you have computer problems?   Yes   No

If yes, what problems did you have? _________________________

____

Was this unit different from what you have done in your science classes before?

About the Same   Somewhat Different   A Lot Different

How was it different? _________________________________

____

How would you rate the web site "Fysics is Fun!" based on the ease of use?

Hard to Use   Somewhat Confusing   Pretty Easy   Very Easy

How would you rate the content of the web site "Fysics is Fun!"?

Confusing   Somewhat Confusing   Pretty Clear   Very Clear

What was the most helpful part of the web site "Fysics is Fun!"? ______________

____

What was the most difficult part of the web site "Fysics is Fun!"? ______________

____

On a scale of 1-10, with 1 being low and 10 being high, what overall rating would you give the web site "Fysics Is Fun!"? ________