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MULTI-MEDIA PHYISCS

An Interactive Qualifying Project Report
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Degree of Bachelor of Science
by

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Date: October 8, 2003

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October 8, 2003

Dear Dr. Koleci:

Attached is one copy of the IQP: Multi-Media Physics, Project Number CK-0003.

Sincerely,

Rachel H. Nasto

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Dr. Carolann Koleci: 1 copy
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Abstract

The objective of *Multi-Media Physics* is to determine the effect of a unique learning environment in which students can actively explore fundamental physical phenomena, using popular media to exploit conceptual understanding. In this experiment popular media was used to assist the student in relating a concept taught in lecture to a visual situation in the film. In order to achieve this objective the students were asked to work out problems created by different situations in a variety of movies. My hypothesis is that a relaxed and interesting activity will stimulate the student's interest in the material, resulting in a better understanding of the concepts. Overall, students found the sessions to be helpful in extending their understanding of the material. This report will include results and a discussion on teaching physics concepts through popular media.

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This project *Multi-Media Physics* was created with the purpose of assisting students in learning physics by stimulating their interest with modern day media. Supplementing the lectures, conferences consist of smaller populations of students (i.e. 30-40 students), provide a learning environment that is more personable, and allow for the reinforcement of lecture material. In addition to these resources, students had the opportunity to attend practice sessions which incorporate introductory physics problems into modern-day Hollywood movies. I hypothesize, if students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented. Students will be able to better retain the information presented in these sessions because of the strong visual emphasis.

Through watching movies, students will be able to apply information they have learned in the classroom to other simulated situations. Movies will be used to assist students in visualizing problem situations. Two main activities movies will provide are calculated problems and presentation of concepts reviewed in lectures. Students will be required to select five concepts in the movie and explain the phenomenon that either could or could not be possible in the physical world, based on what they had learned in lecture. By requiring the students to identify concepts and explain their components students will be able to associate scientific language with a visual representation, making it less confusing for introductory physics students.

Movies will also allow students to realize that physics applies to all aspects of life. Many Students often have difficulty making associations in technical subjects from the concepts presented to real life situations, the movies will present a semi-realistic view of physical concepts. Through identifying particular concepts demonstrated in the chosen movie, students will be able to associate technical concepts to a concrete visual example. Since many students have a particularly hard time relating concepts to real life this particular exercise will provide students with a working example. In this case many concepts professors view as simple will become more clear to the students who are often slightly confused since they can see now where the physics actually applies. This visual exercise will help students master the skill of visualization, which has proven to be very difficult in most cases. Students are usually shown how to solve problems through drawings on a chalk board, they most times, never make the association between the physics around them and what they are being taught in the classroom. Also since the physics they are being taught is theoretical and very often ignores the smaller components of their universe it can become more separated from their real world. One of the purposes of this project is to help students realize the physics in their world and make connections that will help them to understand the mathematics and concepts they are being taught.

In creating physics practice problems, which apply to movie situations, students, will be able to relate obscure concepts, such as angular acceleration, which can be very confusing for students, to familiar situations. Many students have experienced educational systems in grade school and high school, which included a multimedia focus; this exposure has fostered the development of a more visual learner. For example, many students have difficulty creating a diagram of simple mechanics problems. The problem is not in creating the diagram's components it is relating that diagram to situations; such as throwing a tennis ball off of a roof top. To assist students in creating diagrams and visualizing situations to accompany the diagrams, movies will be shown. For example, many first year students forgot smaller forces, such as friction, when drawing free body diagrams. This seemingly minor oversight can affect a problem very seriously; yet a student would never notice. This is because when students look at a word problem they do not see reality; they see a hypothetical situation that does not relate to their physical world. In showing movies students automatically associate actions with the real world and therefore are less likely to forget the minor details. When they see a man falling down a hill, they realize both gravity, friction, and the earth are playing important parts to his descent. By drawing a diagram to mimic these situations students will have a concrete example for their imagination to work from.

Not only will the movies serve to teach students about physics they will also assist in creating a relaxed atmosphere in which the students can learn. It is hypothesized that the movies will transform the learning environment from one consisting of a large population of students to one composed of a small group of students in which students can become comfortable enough the traditional lecture situation, which can be extremely intimidating, and put them in a small group of students where they can become comfortable enough to ask questions and participate in demonstrations. These students when asked to come to the board to answer questions will feel more confident experimenting with equations and concepts they are unsure about. In this case we see that when students experiment with information learned in class they are able to make associations more easily and see multiple solutions to problems given in class and on tests.

Through creating this particular learning atmosphere, students will more readily incorporate information and interpret word problems. By integrating a fun activity into physics lessons students will be more enthusiastic about the subject and therefore devote more time and energy to understanding the concepts presented in class. This enthusiasm will create a mindset helping students to learn a difficult and sometimes intimidating subject matter. Acknowledging that student interest is responsible for a large portion of scholastic success, I predict that once students become enthusiastic about the information they are learning, they will achieve a better understanding of the material presented as well as higher classroom scores.

2.0 Background Information

Many people have experimented with ways to engage students in scientific information. Professors have found that many students are either disinterested or frightened by the mathematics behind scientific concepts and therefore do not take the time to learn them properly. One of the more successful hypotheses is that not only is the mathematics frightening but the learning environment is as well. Many professors are presently studying the effect of environment on student's learning. The general verdict, at the moment, is that students learn more readily when they are in a relaxed environment where they can interact with the material being taught. Several experiments have been performed using popular media to teach students about physics and other scientific genres. Some of the more prominent experiments are those done by Dr. Efthimiou who uses movies, Dr. Kakalios who uses Spider Man comics, and Prof. Freudenrich who uses books, movies, and television shows, which focus on science, to demonstrate concepts. These educators all hypothesize that not only is science the problem but also the way in which students typically learn science. In this case they strive to find ways in which students can feel comfortable with information presented while not having to dilute the material.

2.1 Effects of Learning Environment

The learning environment students are presented with is extremely important. In most cases it can make the difference between fifteen percent of the class understanding what is happening and ninety three percent.[4] There are a lot of inadequacies in traditional instruction. It is believed that while there is ease in teaching in the traditional method this method is inadequate for giving a complete understanding of the material presented. In an article titled *Promoting Active Learning Using the Results of Physics Education Research*, the authors believe there are a few factors , which contribute to a poor learning environment. These things are:

> "Solving quantities problems is inadequate for a practical understanding of material
> Traditional instruction does not promote a strong conceptual foundation, many students only memorize formulas without any understanding of the meaning behind the formulas
> Traditional instruction does not compensate for typical conceptual difficulties
> Student's reasoning ability is not an affect of traditional instruction
> Student's have difficulty forming connections among concepts and the real world after traditional instruction
> Teaching by telling" is not an effective instructional technique for most people."[4]

These six concerns are common among informed educators; many have attempted to use different teaching techniques to assist students in learning the information.

One of the most popular alternative learning techniques is "hands-on" laboratory activities. Students are required to perform an activity that will involve peer instruction to keep them engaged in the material. This will assist students in breaking the typical learning cycle , which is perpetuated by the traditional learning atmosphere. This kind of a learning session is encouraged to start with a prediction session. Students are shown the demonstration and then asked to predict what results will be achieved. The students are then given materials to replicate the demonstration and compile the resulting data. This active learning style has students describe what happens in the lab, predict the outcome, discuss with classmates the results, and then carry out the demonstration. In most cases they use their peers to discuss connections to other concepts in the class because a positive result from the demonstration will not be possible with out the previously taught concepts.

These teaching techniques, while seemingly simple, have a large effect on the students' ability to learn. In one study of 1200 students who were taught calculus-based physics traditionally only thirty percent understood the material.[4] When taught with the new method seventy five percent of students understood the material. In a similar study of students who were taught algebra-based physics traditionally only fifteen percent understood the material. When taught algebra-based physics using the new method ninety three percent of students understood the concepts.[4] This data shows that it becomes easier for students to learn the material if they are given an activity they are familiar with. While in this particular study students preformed a laboratory experiment they could do a hands-on activity, and it can also be through other methods they associate with real life.

Moving from a traditional learning setting to a more student "friendly" atmosphere is not as difficult as one might first think. Using multimedia such as television or movies can be an easy first step. If used properly

> multimedia can, through it's power to animate, communicate dynamic information more accurately than a diagram and can help students visualize phenomena that cannot be seen, for example chemical reactions[4]

In this case students are able to examine the components of a movie clip and truly understand the aspects of the problem in more detail. For example students in a physics class who are shown movie clips and asked to evaluate a problem corresponding to those clips will be able to associate that real life situation with a set of equations. This association then transfers from the problem solving session to the test where a similar problem is given. By remembering the clip in the movie they more easily draw an association with the problem and are able to solve it more easily.

2.2 Joliet Junior College

Dr. Curt Hieggelke runs an experiment in which he depends upon students to take an active role in learning. In this case the students seem to be more easily self-motivated when given fun and interesting activities instead of traditional lectures. Dr Hieggelke "became convinced that no matter how much [he] told [students] the right answer, they still didn't pick it up, that becoming a better lecturer doesn't have a better impact on them."[3] As a result he believes that students need a learning environment in which they can learn actively. Dr. Hieggelke demands his students to participate in the learning process using computers to analyze data. Students seem to respond positively to the active learning not only because of the technology involved but also because of the knowledge gained from the computer programs. Many students who are familiar with computers, find learning easier when the information is presented through that medium. This particular software program allows students to create visual patterns from their data. They use the graphical representation to avoid getting lost in the data, setup, and collection that are incorporated into the labs. Students are also able to set different parameters to instantaneously asses data. Most students seem to find these features extremely engaging and as a result learn the concepts more easily.[3]

In this active learning environment the students use group work and projects to assist in learning more about concepts taught in lecture. These situations force students to explore concepts more deeply then they would ordinarily. Since the students are able and encouraged to take an active role in learning they become more stimulated and can learn the material more thoroughly. Using pre and post tests that asses the student's conceptual knowledge as a measure of the knowledge learned, Dr Hieggelke has learned that in this particular situation students learn more when they are given the chance to explore concepts on their own. Alan Van Heuvelen notices that

> When you plot Hieggelke's students' post-test results on the Force Concept Inventory along with the results of students taught by other faculty who see the interactive engagement approach to physics, his students' outcomes compare favorable with those of students taught by Eric Mazur at Harvard University.[3]

This particular quotation is especially important because the students at Joliet Junior College have not been accepted into an ivy league school but are able to perform at least as well as their counterparts in those kinds of schools. The difference in the learning environment is the shift of responsibility. The professor is no longer in charge of telling students the information they need to know for the exam, he is merely there to assist students on their journey through physics. This method of teaching has proven to be very successful because an extraordinary number of students are willing to take control of their learning experience if given the chance. The difference seems to be in the interest of the student no matter the learning level.[3]

2.3 University of Florida

Dr. Efthimiou, from the University of Central Florida, uses movies to present physics concepts to introductory students. This is another example of an engaging environment for students. Dr. Efthimiou states, "[Students] come to class the first day and always ask is it going to be hard is it going to have a lot of calculations and formula's?"[1] Indicating that they are not afraid of the concepts but the mathematics and other seemingly hard scientific methods that are incorporated into gaining a full understanding of physics. His method of alleviating those fears, however, is through looking at movies as demonstrations of un-real life.

Some of the movies Dr. Efthimiou uses are *Speed 2*, *Tango and Cash*, *Eraser* and *A Space Odyssey 2001*. *Speed 2* is used to discuss motion in general, *Tango and Cash* is used to evaluate how electricity works, and *Eraser* is used for momentum. The movie *A Space Odyssey 2001* is used to give an example of good physical principles in a movie. This movie concepts that are presented in a realistic way such as rockets that are silent when moving through space and the centrifugal force creating an artificial gravity.[1] This is particularly useful because students can see examples of true physics while watching a fictional movie. In these few cases the movies are used to show students what "bad" physics looks like. Many professors use the term "bad physics" this means that a movie or television show will not make the characters strictly obey the laws of physics. This is sometimes seen as a backwards way to teach physics but in reality it is just as effective as teaching physics using examples with "good" physics in them. In this case students can calculate the ideal case and prove the movie wrong, giving them a visual to associate with the equations and the ability to calculate a situation that is not perfect.

2.4 University of Michigan

Another assistant professor at the University of Michigan, Dr. Kakalios uses comics such as Spiderman to engage students. In this case as the concept is addressed in the comic book Dr. Kakalios teaches his students the information needed to explain the elements of the story.[2] This class, while taught for non-physics majors, changes from the traditional teaching style to one that engages the students which is extremely effective in teaching the concepts associated with equations and mathematics.

In one situation Dr. Kakalios analyzes the statement that superman can "leap tall buildings in a single bound." In this case he shows his students that for superman to have that kind of strength he would have to come from a planet eight times bigger than earth. He then explains

> "You can make a planet eight times bigger, but then they tend to be gas giants, like Jupiter. You can't really make a planet eight times denser, because the density of matter is really set by inter-atomic forces."[2]

He moves on to explain that if Krypton was a smaller planet with the core of a super-dense neutron star material then it is possible for his planet to be that dense. Furthermore if the core was a super-dense neutron star then that would also explain why Krypton exploded. In this case students learn not only about mechanics, density, and astronomy but they have a concrete example they can relate to.[2] This is particularly important because they not only have a conceptual knowledge of these topics but also a practical knowledge. Since the students have seen the physics through a medium they are familiar with they are more comfortable relating it to a visual example which is a very important skill to develop when working with physics. While Superman comics do not emulate real life, they are in a genre students have been interacting with since childhood and so they are very familiar with the examples presented.

2.5 Duke University

Professor Freudenrich at Duke University uses the Talent Identification Program to test his methods of teaching college science. His students are seventh to ninth graders who have come to a short summer program to learn more about math and science. Professor Freudenrich states

> "keeping students motivated is one of the greatest challenges for science teachers today. One way to stimulate and maintain interest in science is to set a contextual framework for learning, and one powerful and flexible framework is the study of science fiction." [5]

In this case the professor is able to teach middle school children college science through movies, television, and books. This method of teaching uses all three genres of popular media to engage student's interest and teach them concepts that would normally be out of their realm of comprehension.[5]

Professor Freudenrich gives a lecture to introduce the scientific principle and then discusses the integrity of a model in a movie. In this case the accuracy of the model does not matter only the student's ability to identify concepts and relate them to a situation they are familiar with. He then gives students a movie where they have to investigate the concept in a specific clip. In this case they are forced to ask questions that will lead them to learning other concepts that pertain to the first question. By doing this they are able to expand their knowledge base not only by lectures but also by personal inquiry. The students are then given a quiz on the concepts presented in class to make sure they understood all that they were researching.

After researching science in the fantasy genre students are given a factual article on the scientific concept and asked to discuss the possibility of things such as colonizing Mars, based on what they have learned.[5] Novels are used in much the same way. Students read novels such as *Mars* and then compile a list of topics that are associated to the concepts they are learning in class. Things such as interplanetary trajectories, artificial gravity, and Martian gravity are addressed and then studied in news articles. After the students gather the appropriate information they explore the aspects of a ship to transport people.[5] One project involves students building a space ship and then describing the engineering concepts behind building such a ship. In this case they are able to understand concepts that should be completely out of reach because they do not have the mathematical background to grasp the concepts. However, through a genre they are familiar with and like the concepts engage the students and this interest helps them to grasp what is being taught.[5]

3.0 Methodology

3.1 What was the project?

This project *Multi-Media Physics* was created to evaluate the effect of learning atmosphere on students. The first thing needed was a sufficiently different atmosphere from those the students interacted with in lecture and conference. To create this atmosphere all that was needed was a change in teaching style. In this case a new instructor was brought to teach students in an after-hours study session. Students from two conference sections were invited to attend and were given an incentive of two extra 100% quiz grades to help boost their average. The session then started out with a contemporary movie and at various points during the movie the instructor would stop, and use the concepts students had learned in lecture to evaluate the situation. The topics covered were vector calculus, kinematics, work/energy concepts, and torque. These topics, in the class as in the problem solving session, are divided up into four different tests, so each study session was a review for the upcoming test.

The most important aspect of this project was the atmosphere created. As stated above, in the hypothesis, the atmosphere students learn in directly effects how much of the information taught they actually learn. To achieve the comfortable and enjoyable atmosphere that was desired students were given cookies, pizza, and soda to start the session. The reason they were provided with this particular food was many students are accustomed to having foods such as these when spending time with their friends. In providing them with the food, from the beginning of the session the attitude was changed. Many students became more relaxed and were more willing to learn and answer questions based on the presentation of the room from the time they walked in. While all students that attended the sessions were adults, it was important to help them feel relaxed from the start. Pizza and cookies are not the only reason students responded well to the sessions but the initial gesture helped to alleviate any preconceptions about what the session would be like.

3.2 How was the project executed?

Aside from presentation of the room students were also given the opportunity to learn physics through movies. The hypothesis had been that students would become more receptive to learning information if the learning atmosphere was changed. In this case we saw that students were better able to learn concepts for the test in the atmosphere created by the problem sessions. Some commented that the movies helped them to visualize situations in which concepts could be applied, helping them to gain a better understanding of the material for the test. Based on their pre test scores one would conclude that many of the students who attended the sessions were in the lower middle of the class, in terms of comprehension. Many of the students who came to the problem sessions did not have a grasp of the information and were looking for ways to improve their knowledge before the examination. In the assessment in section 5.2 students' pre-test grades were approximately three points lower than that of the class average. In the beginning the majority of students who attended the sessions were, when called to the board, unable to answer the problems that had been created because of their lack of physics comprehension. Towards the end of the session, however, almost every person was able to answer questions, apply formulas, and evaluate the situations presented in the movies. This improvement was vast and the students showed a real understanding of the material. Assessing students' test results in section 5.2 one can see that they clearly understand the concepts presented in the problem solving sessions.

3.3 Why were movies used?

Using movies to relate real life situations to the concepts presented in lecture is a very difficult task. No situation, in a movie, ever emulates reality exactly but neither do the theoretical concepts. So in truth, a person who is trying to teach physics must take situations that resemble the concepts and are similar to situations in real life, instead of confusing students by adding too many variables to a problem. The movies used in this particular project were *The Matrix*, *Planet of the Apes*, *The World is Not Enough*, and *Rush Hour II*. In this case the movies were chosen based on student suggestion and their ability to provide examples of the various concepts that would be on the test.

Movies were also used because of their ability to give students a visualization of equations. In seeing the concept demonstrated on the film they were able to relate a real life situation to the equations given in class. One of the hardest things to do in a physics class is to provide oneself with an appropriate visual example of the concepts. While professors attempt to use simple examples such as a ball falling or being thrown across the room, these examples are so mundane students have trouble relating them to problems given in homework and on tests. The students are already interested in watching movies and they have more of an attachment to this form of media. The movies, while not traditionally "educational", are a genre that students are comfortable gathering information from and are more receptive to learning when concepts are presented in this fashion. This was also a large factor in helping students relax. By presenting them with a form of media they are very familiar with they have an easier time absorbing the information presented in the session.

3.4 What movies were used? Why?

3.4.1 The Matrix

The Matrix was used to demonstrate vector calculus. This movie was chosen because it presents a situation where reality applies but only when the characters have decided it fits best into their plans. In many situations the characters in *The Matrix* defy gravity and the laws of physics. While this particular movie is not very suitable for presenting kinematics, work/ energy, or torque concepts; there are a number of instances where the characters defy gravity and create very visible vectors. Since this mathematical concept is particularly new to students it is helpful to use a movie where the movements are very pronounced and deliberate.

The first problem students were given came very early on in the movie. Trinity, one of the characters, has jumped in the air, her feet tucked underneath her body and her legs forming an obtuse angle. In this situation Trinity's legs became vectors and students were asked to find the resultant vector. This analysis, while unorthodox, was able to catch student's attention and hold it for the rest of the session. In using such a bizarre example for the problem, students became curious to see what the new examples would be and therefore paid more attention to the problems than they normally would. This particular example was also extremely simple which helped students to identify the two particular concepts of vector addition and angel analysis.

The second example used was a situation where Trinity jumps from one building to another. In this case where she has jumped downwards and appears to fly approximately thirty feet into the window of a parallel building. In this case the mechanics are impossible, students see that gravity seems to no longer apply, but Trinity is creating another vector. This example was particularly good because students were only able to see the resultant vector. In many problems students are given only resultant vectors and have to find the components using an angle only mentioned in the problem. The example created forced students to figure out where the angle was and how they had to asses it. This second part of the question also forced students to identify when to use $\sin\Theta$ and $\cos\Theta$ which seems to be a common problem. Students were then asked to evaluate the components of the vector given the hypotenuse and angle. This problem is similar to that of a ball with no gravitational constraints, when students have seen the action performed by humans in a context where it makes sense the action becomes more real for them. This is true of any kind of example though. When students have background information that answers simple questions such as "Why would that happen?" they are free to clear their mind of simple concerns and learn the information.

While this aspect does not concern many professors sometimes students need the situational constraints to see where the concepts apply. This is especially true of students who try to see a problem from all aspects. Not only do concepts became a factor but where, when, and how also factor into the student's understanding. Instead of having to create those situations themselves while trying to learn the information presented the movie provides them with all of the information necessary to focus on just the physics and mathematics.

In the third example was another character, Neo, jumps from a rooftop and bounces high off of the pavement. This action creates two vectors one entering and the other exiting. In this case students evaluated the components of these vectors and then find the resultant vector using the components. The situation while again impossible, did provide an excellent example of vector addition. The measurement created by Neo was two very clear vectors. There was also time in between the two motions giving students two distinct situations to analyze. They were then able to see where vector movement would apply, while this situation was not feasible in reality, they were able to see a situation where vectors were created from movement instead of just given to them.

3.4.2 The Planet of the Apes

Planet of the Apes was used to demonstrate kinematics concepts. This particular movie was picked by the students. Since the students were able to pick the film they were more involved and it took less time to help them relax and become ready to learn. *Planet of the Apes* was a particularly good example because the film was made in 1968 when the ability to create special effects was very limited. This meant that the director was forced to abide by the laws of physics and therefore presented many accurate examples. As well as a lot of movement, allowing students to observe a variety of situations that apply to physics.

The first problem students were given was a force problem. One of the characters falls down a hill, as he is sliding I asked students to create a free body diagram and force equations based on their drawing. The students were able to see almost all of the forces acting on the person and were then better able to create an accurate diagram. While this situation is no different from the situation given on a test where a person is performing an action; the only difference is that instead of a stick diagram students have an actual picture to refer to. As stated before, the effect of using a human as opposed to a stick figure gives students a picture based in reality for them to work from. The immediate connection to reality helps students remember the physical laws that apply. In seeing the man fall down a hill, they recall that gravity and friction apply. Then on the test they are able to remember back to that particular part of the image and relate the situation to an example on the test.

In the second problem given, one of the characters was throwing fruit from a tree, down to some villagers on the ground. Students were again asked to create a free body diagram. They were then asked to use position and velocity equations to evaluate the time and distance the fruit would travel from the top of the tree to the bottom. Again, this problem is no different then a tennis ball being thrown off of a roof and even exhibits the same motions and shape of a projectile, but since it has context and students see the physical example they are able to understand the relevance of the problem. As stated above, many students have trouble with physics because they do not see the relevance to the real world. No matter how hard the professor tries to give examples and different situations to help this problem they are still unable to understand.

This is not particularly telling of the students' intellect, but of the way in which they learn. Today's technology is centered around television and computers. Previously students' education sessions included educational videos and computer work. Since students are accustomed to gathering information from simulations on a television screen, it is easy for them to learn from movies. While the instructor still uses the board and traditional diagrams, the movie is another example for students to observe. Many students commented that after seeing the movies they realized the relevance of physics equations to the real world. In seeing the relevance it was translated from an abstract concept to a problem that could be related to something in the real world. In this case students were able to understand the concepts better because they had a reference point to relate to (See 5.1 Survey).

The third problem given to the students was one where a character jumps from a cliff into a body of water. Again students were asked to evaluate the free body diagram, but this time they were asked to combine questions one and two. They were asked some conceptual questions about the distance equations and then they were asked to evaluate the force equations. To evaluate the force equations students had to use a free body diagram to find all of the forces acting on the object. This question was asked was because many students get confused when there is an action being performed such as running or jumping. Most students can identify the majority of the forces present, but neglect smaller ones such as friction. Also, some students get confused as to which direction gravity is then acting. By showing the students a problem where all of these elements are combined they are able to see how the commonly overlooked forces take part in the larger picture.

3.4.3 The World is Not Enough

The World is Not Enough was used to demonstrate work/energy concepts. This particular movie was a very good example of work/energy because it uses a lot of collisions and situations where work problems are easy to evaluate. Situations such as moving up or down an incline and various things colliding are very numerous. This movie was particularly useful not only for the variety of situations but the prolonged activity. For example: in one scene, where Bond skis down a hill, it takes approximately two minutes to perform and gives students time to analyze the action and apply the right concepts.

The first example used was very early on in the movie where a man is shot. Students were asked to evaluate the velocity of the system after the bullet hit the body and then the moment of inertia of the bullet. In this case students were able to see a situation in real life where there was an inelastic collision. Since these situations do not happen very often it is a particularly hard concept to see the relevance of. Students have a hard time evaluating what is and is not an elastic collision because they do not have many real life examples. One instance that is commonly used by professors is pool balls. Since they create an almost perfect elastic collision it is easy to replicate and students can see a physical example. The inelastic collision, however, is harder to demonstrate. So while students are able to easily identify an elastic collision but inelastic collisions are extremely hard for them to visualize and evaluate. This collision was not completely inelastic but it gave students an idea of what one looked like, and therefore helped them to evaluate the problem given.

The second situation used was when a character is jumping from a plane to ski down a mountain. Students were asked to evaluate the work done by him from the top of the mountain to the bottom. In this case they were able to see a situation where a person did work, but was not actually doing the lifting or carting. While he was sliding down the mountain the system including the character and skis was moving but the components were not. In many situations work is presented in a context where the human element is not only doing what a physicist would consider work, but also what a person would consider manual labor. This can become slightly confusing because both definitions of work are being used at the same time. In this situation the character is merely standing on his skis while they bring him to the end of the slope. Students are able to see that a person or an inanimate object can have work done on them, while not doing work themselves.

The third situation used was two helicopters flying towards each other and colliding. Students were asked to evaluate the collision as if it were completely elastic. This problem proved to be more difficult then originally planned, only because students were trying to dive deeper into the problem than had originally been intended. Unlike the previous sessions where they had just tried to absorb the information, students started to ask questions about the mathematics and evaluate the situation in a more complicated manner. Since they did not have the background to solve the equation they had created, it was slightly confusing. But it shows, as Dr. Hieggelke hypothesizes, that the students were starting to take over their education instead of taking a passive role. As they became more active in the problem solving students were able to understand concepts more quickly and apply equations to various situations.

3.4.5 Rush Hour II

The last movie used was *Rush Hour II*. This movie was used to demonstrate torque concepts. Since many of the karate moves done by Jackie Chan involve spinning this made the movie perfect for the students. Many of the karate moves done by Jackie Chan were also very independent, such that Jackie did the moves without touching anyone or anything. This was particularly ideal because only the force of gravity and the initial force were acting upon him. Students could easily grasp the pure concepts instead of trying to wade through a lot of different forces. The students could analyze these mechanically simple problems and then apply the equations to more complicated ones.

The first problem created was when Jackie Chan and Chris Rock are fighting on bamboo scaffolding. Both men are climbing the scaffolding when one of the bamboo rods breaks. The rod carries them in a quarter circle and is stationary for a short amount of time. Students were asked to evaluate the force equations of this situation supposing that the shoot was like a beam supported by wires rather than bamboo. In this case, students were not only able to evaluate the problem in front of them but they were also able to adapt to another problem very quickly, which was the more important concept for students to learn.

In the second problem students were asked to evaluate a situation where Jackie Chan did a spinning move pushing himself off of the ground with one hand while being pulled off of the floor by the enemy. Students were told to evaluate the rotation of Jackie's center so that it would lend itself more easily to the problems they would be doing on the test. They were also asked to create force equations and calculate, angular acceleration, moment of inertia, and work done by the situation. In this case, students were able to see how all three concepts connected to each other by evaluating them on the same situation. This particular problem was created because students very frequently have to evaluate situations where a tube is being pulled on by two wires in opposing directions. Since Jackie is not quiet a tube students were asked only to evaluate a core section that had a set radius and spanned the entirety of Jackie's torso. This was then very similar to problems they would be asked to evaluate on the test.

After each problem solving session it was obvious that students had gained a much better understanding of the material. Since they had a reference point they were able to adapt situations from the movie to situations they would be given later. Many of the students commented that evaluating concepts in relation to the movie was much more helpful then just evaluating a situation from lecture where there aren't any contextual examples. It would seem that since students were more interested in the genre used to present the information they were more receptive to learning the information. During the sessions they became engaged in the material and after a few minutes would willingly come to the board and answer questions. Another interesting aspect of the session was that students were not afraid of wrong answers. One large problem in calling students to the board to is that students are afraid of being wrong and are embarrassed by their mistakes. Most of the students who participated in the problem sessions became very willing to answer questions and do problems even if they were not absolutely sure if the method used would work. This was a large breakthrough because it showed the students comfort level had been raised from that of the average lecture session. Since students were more socially comfortable they were able to concentrate on the material being presented. They were then able to learn information more quickly and as an effect solve problems more completely on the test.

4.0 Why Movies?

Many professors have used different methods to motivate students to learn concepts pivotal to understanding science. Some have used java applets, PowerPoint presentations, comics, sci-fi novels, and a wide range of other mediums; movies were chosen for this project because of their ability to appeal to a wide range of people. Movies were also chosen because they are easy to present to people and take a set amount of time to finish, whereas novels and other genres can take varying lengths of time for people to finish. The movies chosen were contemporary movies, because they hold more appeal for students, they can then relate something they are familiar with to the seemingly foreign physics concepts.

Since the, hypothesis was that a relaxed and interesting activity will stimulate the student's interest in the material resulting in a better understanding of the concepts. I used movies that I know students were already interested in, in order to motivate them to learn the material. Using the scenes in the movies students were able to study the mechanics of a situation. For example, when a person is falling from a roof top, students saw a physical example and then drew the resulting force diagrams. Students could create force equations and analyze the mechanics equations that pertain to the situation.

Since many students find it very difficult to create a visual example from a problem description it is important to help them find resources that can give aid their visualization by connecting it to real life. This means that people must act out the activity, which is why action movies are the perfect genre to present these concepts. If shown these situations students who once could not relate equations to problems, then find it easier to create a visual that will help them find the answers. This is especially true for force diagrams. When students make a force diagram from a stick figure they often forget smaller forces such as friction. When they see the object in space during the movie they have a clear visual and they have an easier time identifying the forces involved. Using movies the students were able to see real people performing actions that display various concepts. Students then have a visual example that they can relate to another problem on either an examination or homework set.

It is extremely important for students to be able to come up with their own visuals. Movie sessions might look like they are giving the students too much assistance; however, they are not. Since problems are have multiple variations students must modify the example given in the movie to fit the particular problem. In this case they use the same base but must add or subtract certain details that are crucial to the solution. The movie is just extra aid so they fully understand the process by which physics, because physics after all describes the real world. Many students commented that being able to analyze problems in the movie made it easier to visualize problems on the test.

As stated above students were served pizza, soda, and cookies; while this may sound extreme it was part of the attempt to make them feel comfortable in the learning environment. Since students were relaxed they were more receptive to the information being taught. The food and beverages helped create an atmosphere closer to that of their dorm room when studying with friends. In this kind of a setting, students typically feel comfortable and are able to relax but since they are no longer absorbing information the atmosphere only helps while they are attempting to work through problems. When they were given the same kind of atmosphere in an actual learning situation it helped them be more receptive to the concepts being presented. Since the material frequently intimidates students it is beneficial to help them relax before starting to teach the actual concepts. Once relaxed they are less likely to be afraid of the concepts and will be more willing to overcome mental hurdles.

Students commonly find the concepts and mathematics challenging , causing them to shy away from difficult problems. However, when they feel comfortable with the information; exercises given in class and for homework the work will be more easily completed. The harder questions will no longer be an issue, since the students no longer see it as an daunting task. While the students were watching the movies they were also solving problems very similar to those given on previous exams. Since these problems are given with the intention of testing the student's knowledge they were, on a relative scale, medium/hard in difficulty. While they were not the hardest questions given they were challenging and tested many different concepts all at one time. Students had no difficulty solving the problems after seeing an example of a slightly similar style.

After being shown one problem students were able to come to the board and apply the concepts to different and complicated scenarios and problems. Many of the concepts students had trouble applying their knowledge to in the beginning of the session, more quickly mastered during the sessions. Even though the concepts had been presented in conference and lecture previous to the problem solving session, students were still unsure of the way in which they should be used.

During the problem sessions I required students to come to the board and participate. This was because students can very easily copy down the material presented in lectures and learn very little from the demonstrations. Students then become inactive and do not pay as much attention to the details of a solution as opposed to having to either solve the problem themselves or help a classmate solve the problem. This participation is a quick and easy way to help students to take an active role in their learning. Since it has been concluded that students are very willing to take the dominant role in their education if only given the chance, it is extremely important to give them that opportunity. In making students come to the board they had to pay attention and truly understand the concepts so they could apply them to other problems presented in the problem sessions.

Since it took such a short amount of time to teach them how to use the information given to them in class it is evident that their state of mind is an apparent effect on their ability to perform well. This conclusion is reinforced by the positive responses given, by the students, on the survey distributed after the sessions were over. The difference between lecture and the sessions was only that students were asked to participate and the genre used to present the problems was movies instead of hypothetical situations. Since they were in a more relaxed atmosphere it became easier for them to think through problems and try to completely understand what was being taught.

It is always a struggle to have students volunteer to come to the board. Since they are usually very unsure of their methods and afraid of being incorrect it is usually the case that the instructor has to, almost literally, drag a student up to the board. An unexpected conclusion of my experiment, I have found that the atmosphere a student learns in also effects their participation. When students feel that they are in an atmosphere where relaxation is possible they are more willing to try difficult concepts even if they are unsure of the method. Since they become less afraid of being incorrect students begin to volunteer and take the active role, which is the ultimate goal. As Dr. Hieggelke has concluded when students are given the opportunity to take an active role in their education they are more than willing to take on the proactive role and therefore will learn the subject matter better.

In the beginning students also had trouble applying concepts to different problems again as the sessions progressed and they became more comfortable students were able to apply concepts to a wide variety of problems given. Since the students in this group were self-selected they were students who were having a considerable amount of trouble with the concepts in lecture and were looking for some additional assistance. These students were very capable of reaching the types of solutions the problems asked for. They were just unclear as to how equations and concepts applied to the particular questions. Again the movies helped to give the students some context to the problems, with this context they were able to relate the concepts to those situations and provide a suitable solution. As the problem sessions progressed and students were given more visual examples, they became better acquainted with the material and were able to easily apply concepts presented in previous situations to new the ones. Even though there was only a one-hour window to do the problems, the students showed considerable improvement in that short time. Many of the students were able to use all of the concepts presented in previous problems on the last one presented.

While many of the students score average or slightly below average on the tests in class, they had entered the session completely unprepared for the test. Since the sessions were held two days before the test was given students left the session being able to pass the tests and keep up with the class, which was a large improvement. The reason the sessions were held two days before the test was that the day before the test a question and answer session was held so the next closest time was two days before. Many of the students surveyed stated that the problem solving session helped them to prepare for the test. Some specifically stated that the sessions helped them because of the step-by-step solutions worked out in class. Many of the students stated that the real-life situations helped them to visualize the problem better thereby helping them to solve it. Many stated that the real-life situations aided them in forming a connection between physics and life. Once that connection was made physics became more enjoyable and easier for them because they had a basis in which to refer. While students know that physics describes their very world they don't think of the problems and equations in terms of real life. Students see physics as mathematics disguised with concepts and word problems. They find it very hard to relate to anything familiar which creates a huge barrier in students' ability to understand the material (See Section 5.0 Data Analysis).

5.0 Data Analysis

In this case the numerical results make it seem as if the sessions did not help students at all but in truth they helped a considerable amount. In the next section a survey distributed to students is analyzed. Since there was such a small group of students it is most important to evaluate how they perceived the sessions instead of the actual numerical results, because they are not a large enough test group to properly analyze the numerical results, given that they were so varied.

5.1 Survey

At the end of the problem sessions students were given a survey to complete. The questions asked the students to gauge the success of the problem solving sessions. Many students thought that the sessions helped them prepare for the test especially since they covered the major areas of study for the test. Many of the students chose to complete this survey and return it while there were others who were unable. The results from the survey, in this case, are more representative of the session results than the test scores because of the variables involved. The students who went to the problem sessions studied for a variety of different times and with a wade range of effectiveness so the students personal study habits also affected their grades creating some uncertainty in the outcome of the study. Since the students who attended this session were of different skill levels there was not a standard of performance on the test. The students however were aware of their own progress, and since that was the ultimate goal, the survey was designed to display how the students felt the sessions affected their academic performance. Many of the surveys were very positive. While there was one negative response, that particular student had a lot of trouble with physics in the past and was an outlier in every way (All surveys can be found in Appendix A).

5.1.1 Question One

The first question asked was "Did you find the problem solving sessions helpful? Why?" This question was designed to have students evaluate their overall experience with the sessions. Many of the students did not provide as much detail as originally anticipated but the over all consensuses was that the sessions were helpful. Responses to this question were typically that the sessions helped students to review for the test. The concepts presented encouraged the students to think about the material that would be on the test and start reviewing sooner. One student was not as positive because he felt that the session was too detached from the actual concepts to be useful. This is one draw-back to using movies, since the situations are never exactly as one would like, the students have to be flexible. Since some students' thought processes are more structured than others, it is hard for them to use this particular method, but it does seem to work for a majority of students. However, one student felt that the sessions were a "great way to incorporate physics into daily life," thus displaying one of the objectives of the experiment.

When students see the relevance to daily life they can form a connection between the equations and something they are familiar with. In this case reality is the ultimate because pure theory is never demonstrated in real life connection. Since students see the relevance of the material they become more interested because the information is no longer an abstract concept it is intertwined with their world and they can see why it is important information to understand. A lot of students have trouble seeing the importance of learning physics since they do not intuitively make the connection between every day life and the concepts learned; therefore the physics seems uninteresting. In bringing the information closer to the students they are able to become more engaged. Another benefit of using real life situations to analyze problems is that students can then make connections themselves. Word problems can easily relate to situations they have participated in and therefore they are able to see the action in progress and use the equations to evaluate it. Students also are able to use similar situations and slightly change the details to evaluate a different problem. This is the most useful skill of all. When students can modify situations they see they are able to evaluate a wider range of problems easily.

5.1.2 Question Two

The next questions were "What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?" These questions assessed what the student perceived to be the most and least helpful portions of the session. The question was asked with the anticipation that the experiment would be run again so the input would lead to alterations in the presentation. This question also helped assess which portions of the session were most beneficial to the student's academic performance.

Many of the students felt the sessions were overall helpful to their understanding of the material. While there were some drawbacks to this method students seemed happy with the presentation. Some students were able to use the situations in the movies to help relate concepts and remember the application at a later time. For the more rigidly structured student a situation that is not completely congruent with the question asked can become confusing and not help them at all. In this case the student is not harmed by the session, they just do not gain as much from the presentation as most other students.

Another draw back to using movies as examples in physics is the specific nature of situations. Since the instructor is attempting to find a situation in a movie that pertains to a particular concept it is difficult to find a clip that incorporates many concepts all at once. This particular hurdle leads to very specific questions and it is necessary to do a larger set of problems instead of the common method of taking a couple of problems and having them encompass many concepts all at once. Usually during a session of this nature the instructor can only cover a couple of large topics and must leave the students to study the more extraneous questions on their own.

As one student stated "relating problems to movies made it a bit easier to understand how the problem worked and made it easier to remember." The student, in this case, was able to take full advantage of the visual medium and analyze the physical aspects of the problem as well as to relate the concepts to the situation. Some students had trouble with the imperfect nature of the problems. Since one of the goals of the experiment was to give students situations they could completely, visually analyze students who are able to see in one student's words "how the problem [works]" from the movie situations have taken full advantage of the presentation. While other students did not explicitly state this in their answer it was evident they were taking advantage of the visual medium in the way they solved problems at the board.

Another student stated that being made to participate at the blackboard was very helpful. This comment relates back to Joliet Junior College where Dr. Curt Hieggelke proves that students are very willing to take an active role in their own education. By calling students to the board they are forced to actively solve problems instead of copy down questions and solutions as they do in a number of classroom situations. Since they have willingly volunteered to solve these problems they have become more active in learning and will then take the next step to become active on their own time as well. This particular result was not predicted in the preliminary hypotheses of the experiment but has been a positive outcome of this particular activity.

5.1.3 Question Three

The third questions asked was "Do you think that the problem solving session influenced your performance on the exam? Overall? Why?" This question was asked because students' exam performance showed that they were generally below average with their test scores. While this was disappointing data the type of student in the session had not been taken into account. Since students are the best judges of themselves it was important for them to evaluate their own performance. Only they truly knew how prepared they were before and after the problem session.

In this particular case the answers were split. Those who felt the problem solving sessions were helpful, were over prepared for the test. Students who commented that the sessions were not helpful, also stated that they had already performed tasks beyond what was asked of them and were therefore more prepared than most of the students for the tests. Other students who were not helped by the sessions had already resolved themselves to not receiving help and therefore were uninterested in the actual material being taught. The two groups of students with a positive response, were those who were already taking an active role in their education. Those who have already concluded that not taking a role is their best courses of action make it difficult to make a large difference in their understanding.

Those students who needed help for the exam felt that the sessions were very beneficial to their exam grades. Students commented that they learned a lot and understood the concepts more completely after the sessions were over. Although they did not explicitly state why they were able to understand the concepts more thoroughly, one can conclude from the responses to the previous answers that it was the medium in which the problems were presented. In this case we see that students were more interested in learning from movies than lecture, and were therefore more successful in absorbing and applying the information presented. The medium also helped them to create better examples of very common situations used as examples in many of the problems given in homework and the exam. This also assisted students in relating familiar visuals to these seemingly foreign concepts, making it easier to understand and apply.

5.1.4 Question Four

The fourth question asked was "Did you feel more or less prepared for the exam after the problem solving session? Why?" This question was asked because students have varying degrees of preparedness. Since they have the ability to study alone as much as time allows it may or may not help in the preparation for the test. Some students commented that they studied alone but it was difficult to figure out the concepts on their own. The problem solving sessions were designed with that in mind.

Again this question received a split answer. Those students who had over prepared for the exam had little to gain from the problems given in the sessions. One of the students, however, who responded that the problem solving session was just more review, did state that the session did help to solidify things and reinforce concepts. This statement suggests that he was helped by the session and had not yet realized the actual effects. Other students who did not feel they were assisted by the sessions, were those who stated they were not interested in learning because of particular, prior experiences in the course.

Many professors do not have success with doing problems during class. While they know students are absorbing the information, when asked to do harder problems on homework students are often unsuccessful. This is not a result of students being unable to comprehend the information because when the students are interested in the information they are able to do harder problems with ease. Since students are often bored in lecture or very uninterested in the information, they stop paying attention and do not learn the material given to them. When students become interested and engaged in the material, it becomes easier for them to learn harder concepts and apply them to the harder problems. In this case, one would conclude that it is not the nature of the information, or even the information itself that is the problem. It is the way in which the information is presented to students that gives them the hardest time. When using a method of teaching that students find enjoyable, they inevitably learn the material more quickly and thoroughly than they otherwise would.

Those who responded positively to the question said they benefited most from the extra help. One student, however, commented that the step-by-step analysis helped him to understand the problem more thoroughly. In this case, showing students every step of a problem, even the trivial ones, helped to form a more complete picture in their mind. When coupled with the movie situations, they have a visual, mathematical, and conceptual explanation to help them along in the solution. This three step analysis gives the student different ways of understanding the same problem and then helps them to understand the situation using different methods. Once the student puts this complete picture together, they can use different formulas and concepts to describe different situations. As observed above, students were able to solve a wide range of different problems given during the sessions, after being shown only one situation where some of the concepts apply. In this case, one can conclude that students were able to form the complete picture very quickly, and then apply their new knowledge to other situations. This, again, was not a predicted effect of the problem solving sessions, but found to be a benefit in the analysis. Since students have a very good ability to adapt and utilize information, they are able to answer harder problems more quickly after being shown an easier one.

5.1.5 Question Five

The fifth question asked was "Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?" This, as shown above, was pivotal to assisting students in solving problems. Since they very often do not connect reality with the concepts and equations, students need to be shown situations in which they apply. Since the movies were not quite reality, and as pointed out, were sometimes a stretch, it was important to see the response of the student. The main question was: could they extract the relevant information without being confused with the irrelevant information, and then apply that information to different circumstances on the test.

A couple of students responded that they were not always helped by the examples given in the movies. Again, these students were those who had already thoroughly prepared themselves or those who were not willing to be helped. In this case, though the students who responded negatively did comment that if they had been having trouble with the concepts, this method would very likely have helped them to relate to the physics more easily. Since most of the students who responded negatively did comment that there could have been a positive effect, if they had needed help, one could infer that the execution was overall successful.

One student commented that

> The examples related to class problems and allowed us to connect it to both a movie and a certain situation. So then on the test I was able to remember the instance in the movie to remember how we did the problem.

Another student commented "I especially appreciated the examples in the movies because it gave real live examples of these problems and that helped me to understand them better." The students who responded positively commented that watching the movies gave them a visual aid that helped them to relate the situations in the movies to concepts they had learned. In both cases the students felt that the visual aids were extremely helpful because of the way the visual aids related to the problems. Since my goal was to help students relate concepts to visual examples through the movies it was useful for students to specifically mention that on the test they were able to recall the situations and solve different problems. In this case we see that the students were modifying the situations without even realizing it. Since no two problems are alike students were forced to adapt their knowledge to the particular problem given on the test and so they proved that they are able to adapt once given a sound base. These students were not only able to absorb and truly understand the problems but then apply the concepts to different situations.

5.1.6 Question Six

The sixth question asked was "Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?" This question was asked with the intention of having students evaluate the previous question, but in more depth. They were asked to relate equations and concepts to an imperfect model. It was then possible for them to be successful and were they then able to modify the situation to assist with different problems. This was one of the most important questions on the entire survey, because it evaluated the heart of the experiment. Since this particular aspect is the most important goal of the project, it is paramount to assess it's success. Because it is difficult for people to evaluate problems, it was important to know if the students were able to adapt after they had been shown how.

When the students responded negatively, it was for similar reasons as previously stated. One of the students that commented negatively stated that

> Yes, the questions were well chosen to represent the current lecture, such as rotational motion. However due to the nature of the lecture it is very difficult to find questions in popular films that addresses all of these issues.

In this case the student was correct, one of the setbacks of using movies is the specific nature of the situations. Many of the situations found in movies only address one of the concepts taught in lecture instead of covering a variety of topics. Since the problems are so specific, and they do take a fair amount of time, one can only cover a couple of questions in one session.

For this question, most of the students responded positively. Many agreed that the problems helped them with the course work and the questions were chosen well. One student commented that "[he] had to study less because [he] believe[d] [he] understood what was going on after the sessions." Since many of the students responded positively to the previous question one can infer that the problems were helpful. The students were very sure that the method of presentation was very effective, since they saw positive results in themselves during studying and the testing. The students who stated that the examples in the movie were easy to relate to the problems given during the session, also responded that the problems given in the move helped them to visualize different problems in the test. In this case we see that giving students the tools to take an active role in their education, really helps them to be successful on exams and in understanding the course materials.

5.1.7 Question Seven

The seventh question asked was "Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?" This particular question was inserted for future experiments. Since some students are less successful when they study with many interruptions, watching the whole movie could potentially be disruptive. But since the movie gives students context, it could have become easier for students to relate to the problem with the proper context. This was important because it gauged how much context students felt they needed.

The students who responded negatively, did not give enough feedback to know the reason that the questions were not appropriate to the immediate course work. Looking at his other answers to the questions, one will see that he had taken the course several times and not been successful. In coming to the sessions, he was convinced it would not help, and therefore did not gain any benefit.

Students who responded positively stated that their concentration was not effected, and actually preferred the start and stop. One student commented that

> [He] stayed until almost the very end, because [he] liked the movie. [He] only left after because [he] realized what time it was… It provided for a much more relaxed environment and actually coaxed [him] into attending.

In this case, the student was brought to the session because of his interest in the activity and ended up learning more physics and becoming more prepared for the test. Since the student was clearly interested in the movie, it helped him to become more interested in the physics. Another student commented that "it was helpful to stop and start the movie so [one] could remember how the physics really is related." In this case, we see that the students were looking for a connection of the physics concepts and real life. As stated above, while physics is just describing how reality works, many students do not make the appropriate connections. In this , the students not only are able to have a better visual example, but can also relate the concepts to situations in real life. Many of the students who were pleased with the session and liked watching the whole movie, were also students who said that they were greatly helped by the sessions and the visual aids helped them to get better test scores.

5.1.8 Question Eight

The eighth question asked was "Would it have been more helpful to have done individual clips during the session? Why?" This question was designed to reiterate the previous question. Since students may not have considered what the alternative option would be, they were asked to consider the converse situation. Since there would be a lot of little clips shown, it would be start and stop without any context. This could be counter productive because the students do not have any context, and therefore the clips could again become distanced from the student and harder to understand.

All of the students in this case responded negatively because they were more interested in seeing the entire movie. One student commented that "in a choice between individual clips and a streaming, whole, movie I would support the latter. Watching disjointed clips of things is more disorienting and less interesting, overall." In this case, one can see that the students would quickly become disinterested should the session have only included clips instead of the movie. While many professors would argue that watching the entire movie would be a waste of time, it was helpful in keeping the interest of the students. Since the goal of the IQP was to help the students become more interested through a fun activity, it is important to spend a bit of extra time helping them become interested. Another student commented

> If you mean fast forwarding to the parts of interest to physics, no it would not have been helpful. While it would expedite the process of teaching us the material, it would ruin the movie. Without the movie, all we are doing is attending a physics lecture late at night.

Again we see that the students need to have the entire activity to help them feel relaxed and have a good time, thus making them more predisposed to learning the information better.

Looking at the responses of the students, many did not respond very positively. Since many of the students responded positively to the previous questions, it makes sense that given a choice they would again prefer to watch the entire movie. In showing the entire movie, the students were able to gain context and see where physics fits into their world. This context helped students to process the information and make connections.

5.1.9 Question Nine

The ninth question asked was, "Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?" This particular question was designed to gauge students' interest versus their ability to learn. What is known is if students were engaged they should learn the concepts better but it is possible that stimulating their interest did not have an effect at all. In this case students were able to contemplate the new technique and reflect on whether it truly helped or not. Since there are a variety of variables that contribute to the success of a student it is only through the self-evaluation that a student can give helpful feedback.

Some students who responded negatively stated that they were uninterested in the material to begin with and therefore could not be helped. Others commented that their knowledge of the material was already sufficient and they did not need further motivation. In this case the students did not take time to truly evaluate how the session affected their interest or they were uninterested in the material and did not truly take advantage of the session. Since the students did state that they had not been deterred, only not more interested, one can conclude that the sessions did not have any negative effect.

Many of the students, however, responded positively to this particular question. The students felt that the movies made physics more interesting and easier to learn. The students also felt they could relate physics to real life and therefore gave them some context to work from. One of the students commented that

> The [use] of movies helped my interest in physics as they are enjoyable films and it was good to see how it related to life. If you had just stood up there and did the same problems without the movie, it would not have been the same interest.

In this particular case we see that the students were more interested in the material because of the manner in which it was presented. Since the hypothesis directly connected interest to learning ability the students responses help to conclude that the experiment was successful. One can infer that their interest was directly related to their ability to learn. The students who were interested in the material were able to spend more time with the material and see how it applied to real life. Once they applied the physics to other aspects of life, the concepts were easier for them to relate to and therefore easier for them to learn.

5.1.10 Question Ten

> The tenth question asked was "The hypothesis for this IQP was:
> If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
> Do you think this goal was achieved? Please explain.

This last question was designed to make the objective of the project clear. It was important to know if the hypothesis was correct or if it was completely irrelevant to the material. Since students were not told what the hypothesis was at the beginning of the sessions pointing it out to them in the end helped them to reflect on their experience. This question was also designed to give the expectations for the experiment so that students could reflect on the true nature of the experiment.

Those students who responded positively stated that they were able to perform better on the test because they improved their understanding of the material during the session. Many students indicated that they were more able to be interested in the information presented because the sessions were more interesting. One student stated that

> It was much easier to be enthusiastic and pay attention to the problems in a fun setting rather than just sitting and copying down notes. Also it was fun because it was a smaller group of students [as] compared to our huge class so it was more individualized and easier to stay focused.

Many of the students also felt that the smaller group of students helped them to feel more comfortable answering questions and focusing on the information presented. In this case students became more willing to actively participate in the sessions, by voluntarily answering questions and coming to the board and solving problems in front of the class. Another student commented "I think the goal was pretty much achieved because it definitely got me more interested in the topics we discussed. Visual aids, like the movie, helped me to learn a lot better." In this case again the student commented that the movies and atmosphere helped him to be more receptive to the information. Since he became more interested in the material he was then more willing to learn the concepts that had previously seemed harder to understand. In this case none of the students responded negatively and therefore it can be deduced that the students felt the hypothesis was correct and the experiment was successful.

5.2 Results

At the beginning of the course, students were given a pre-test to gauge their conceptual knowledge of introductory mechanics. This test is used at colleges all over the country to test the knowledge of incoming students. Many students in the mechanics class have had the material previous to coming to college so they score very high on the pretest, but that is not the case for everyone.

5.2.1 Test Group Results (Pre and Post Tests)

When the test group was given the pre test the scored-average was 15.11 questions correct out of 30. The median scores for the pretest were 11/30, 13/30, and 21/30 since 11.11% of students achieved all three of these scores. When the test group was given the posttest the mean score was 18.11%. The median scores were 18/20 and 28/30 since 16.7% of students achieved this score. In analyzing the test scores one can see that students improved by three points or ten percent of the total points available on the test. The lowest score on the pretest was 7/30 while the lowest score on the posttest was 8/30. While this was a small improvement many students were able to score much higher than an 8 on the posttest. The highest score on the pretest was 26/30 while the highest score on the posttest was 28/30. In this case one can see a two-point improvement on the highest test score. Not only was the higher score achieved but also it was one of the median scores, showing many students were able to raise their scores substantially. The most concentrated scores for the pretest were between 13-16 and 18-21. For the posttest the most concentrated score was between 17-18. In this case one can see that the most concentrated score was not as high as the previous score but was most definitely higher overall and had more of the students achieving these scores on the second test, thus the average score was higher than the original ones.

Looking at the pretest scores one can also see that the conceptual knowledge of the students in the experimental sessions was extremely low, while there were students who had a lower conceptual knowledge than those in the group, but as a whole they were at least slightly lower than the average of the entire class. Their improvement, however was congruent with the rest of the class, with a ten percent increase the students in the test group started lower and ended lower, but achieved as much improvement as the entire class achieved. (Refer to Appendix B)

5.2.2 Test Group as Compared to Entire Class (Pre and Post Tests)

In comparing the test group to the entire class one can see that they started and ended behind the class in pre and posttest scores. As observed the test group started at an average of 15.11points and the entire class started at an average of 16.2 points. Both groups, however, improved their scores by three points, which is a ten percent improvement. In this case one can see that while the test group's scores were typically lower than the rest of the class these students did show the same amount of improvement. Unfortunately in this case the test group was too small to show any great improvement, but the fact that they were able to keep up with the class, starting from a less knowledgeable position, is a great feat for them. The median score for the posttest for the entire group was between 18-19 while the median score for the test group was between 17-18. In this case we see that the scores are slightly different but not significantly. On the pretest the median for the entire group was between 15-16 while the median score for the test group was between 8-13. In this case one can see that the two groups were vastly different previous to taking the course, but at the end the lower group had caught up to the higher group. This analysis is more important, because while averages take into consideration outliers the median is the most achieved score. Since the medians were so far apart in the beginning their similarity in the last test is an important improvement. This score shows that students were able to raise their scores closer to the rest of the class from a severely disadvantaged position.

5.2.3 Second Test: Kinematics

In this particular class students are given a series of four tests, which becomes seventy percent of the student's grade. The other thirty percent is distributed equally between a conference, lab, and homework grade. In this case students felt pressured to perform well on tests because of the high stakes. The problem session, as mentioned above, was specifically designed to prepare students for their tests and help them gain a full understanding of the material. The first and last tests were not analyzed in this case because of student reluctance. The second and third were more closely scrutinized because of the high return rate of the tests. The way in which these tests will be observed is by matching the questions of the problem sessions to problems on the tests. While no two questions are the same there are similarities that can be easily compared.

On the first question of test two states:

> A ball is thrown from the roof of a building at a 30° angle above the horizontal at a speed of 20 $^{m}/_{s}$. a) Determine the y-coordinate of the ball at the instant the ball has a v_y=-15 $^{m}/_{s}$. State whether this is above or below the starting point. b) At the instant described above, determine the velocity and speed of the ball.

This question is very similar to the second question asked during the second problem solving session. Looking at how the students answered this particular question once can see that many of the students answered part B wrong because they used the equation incorrectly. In this case one can see that the students confused some of the smaller details of the equation. Many of the students earned at least five out of ten points on part B of the first question. In part A of the first question many students received ten out of ten points. A couple of students were confused by the trigonometry of the problem but otherwise were comfortable with the process of solving that particular portion of the problem. In this case the problem done in the experimental session was more closely related to part A.

The second question asked on the test was:

> Draw a free body diagram for the object specified in each of the two situations shown below. Level each force with the name of the object responsible for applying that force. i) Ball swinging on a rope near the bottom of a vertical circle. Ignore air resistance. ii) Tractor pulling a plow at constant speed. iii) For each force shown in the free body diagram of the tractor sketch the corresponding reaction force, also showing the object upon which it acts. Label the reaction force unambiguously.

This particular question was most closely related to the first question asked in the problem solving session. In this case the problem given to students was less, in depth, but similar concepts were applied. Many of the students were able to gain at least twenty-two points out of the thirty available. On part A many of the students were able to earn at least seven of the ten points available. Many of the students who did not earn full credit on this particular problem neglected to take into account one of the forces. While the students executed the problem correctly they did not take all of the components into account. In part B of the question most of the students were able to earn five out of ten points. Again those students who did not earn full credit were missing a force and therefore did not get the correct results. In this case the same forces were commonly missed. On part C of the question many of the students were able to earn full credit. In this case the students who did not receive full credit had again missed a force. This question is a common example of those given to students in our introductory mechanics class. Since all of the parts of a question depend on one another missing one detail can diminish a students chances of gaining full credit. If a detail is missed in part A, the following parts of the question will be incomplete.

The third question of the test asks:

> In the interest of science, a serious-minded student sits on a large scale on a Ferris wheel so that she can measure her apparent weight at various locations around the circular path. The Ferris wheel turns at a constant rate. The 60kg student is located 8m from the rotation axis. a) Draw a free-body diagram for the student both at the bottom and the top of the circular path. On the Ferris wheel sketch, show her acceleration direction at the three points: A, B, C. b) Given that her scale reading is found to be 700N at the bottom, determine the scale reading at the top and the speed with which she is moving.

This question was very closely related to the third question asked during the problem solving session. As stated above, question three of the problem solving session was a combination of questions one and two. Part A of the question seemed to be easy for students. Most of the students, in the test group, achieved at least seven out of ten points on this portion. Since free body diagrams were covered multiple times in the problem solving session most students did not have any problems completing the question. Portion B was not solved as easily, in this case, many students were able to get at least five out of ten possible points. Many of the students were confused by the centripetal motion and did not use the force equations properly. Many other students used "bad math" and therefore got the answer wrong. This particular concept was not covered in the problem solving session. Since students did not have the visual aid or the practice they did worse on the test. Students also had minor labeling errors, which led to larger problems when trying to solve the problem.

The fourth question on the test asked students:

> A workman pushes a 100kg box up a frictional 15° incline (μ=.2) with a force of 400N acting parallel to the incline. a) Draw a free body diagram showing all forces acting on the box as the workman pushes it up the incline. b) Solve for the acceleration of the box and determine whether it is speeding up or slowing down as it moves up the incline. c) The workman now brings the box to rest and walks away. Determine the acceleration of the box after the workman leaves.

This particular question was similar to, but also different from the questions asked in the problem solving session. The first portion of the question was easy for students, all of them achieved ten points out of a possible ten. Students had a large amount of practice in free body diagrams and were well versed in forces before they entered the test. The second part of the question, however, was a bit different. Most students were able to gain at least seven out of a ten possible points. Since the boxes are not going at a constant acceleration all of the time the students have to break up the problem. In this case students would have to apply their knowledge but also use the concepts addressed in the sessions. This question is, however, slightly more involved than the questions asked in the problem solving session. In this case, since students were able to perform well, they showed the ability to apply the information given to them in the problem solving sessions. The third portion of the question was again similar to the three questions asked in the sessions. It does, however, incorporate a frictional constant, which was not addressed in the session. Students, now, had to apply another force and adapt their conceptual knowledge to allow for another force. Most students were able to gain at least seven out of ten points on this question. Some were not as successful and received no points but that was from a lack of effort or time. Many of the other errors resulted from bad math. The other low score all of the components of the question were not taken into account. The correct equation was used but it was over simplified. The students who were able to adapt their information were extremely successful. Again the information presented at the problem solving session set the foundation for students to work through the problem, adapting their knowledge to fit the situation.

One can see that the concepts addressed during the problem solving sessions helped the students understand the concepts well. On most questions that dealt with the concepts presented students were able to gain at least seven out of ten possible points. Since no two questions are the same students were also able to adapt their conceptual knowledge to apply to a different situation. The on concepts that were not addressed, however, students did considerably worse. In analyzing the implications of these results, one can conclude that students did benefit from the problem solving sessions. Since the students who came to the sessions were, at least, slightly behind the other students, they did poorly on concepts that were not addressed in the sessions.

5.2.4 Third Test: Work/Energy

The first question asked:

> A 100 kg box with initial speed $v_i=3\ ^{m}/_{s}$ slides down a frictionless 50° incline while acted on by a constant force F=900N pushing horizontally as shown. a) Draw a free-body diagram showing all forces acting on the box as it slides down the incline. Label each force with an appropriate symbol. b) Calculate the work done by each force shown in (a) during a 2m displacement down the incline. c) Determine v_f, the speed of the box after a 2m displacement down the incline

This question was similar to the second question asked during the problem solving session. Students did not get to practice free body diagrams in this session, but they did have practice in the session previous and performed excellently on the previous examination. All of the students who were in the problem solving session received ten out of ten points on part a. Part b was a calculation of work. This portion of the question was very much like the one presented in the session. Again students who were in the problem solving session mostly received ten out of ten points, two students received eight out of ten for minor mathematical and style errors. Since students were able to perform so well on this portion of the question the results suggest that the problem done during the session was extremely helpful. Many of the questions that students had were answered and they were given a visual aid to assist them through the problem. As stated on the survey many of the students felt that the visual aid helped them to work through the problem during the test. In this case they had a very clear example and were able to apply the concepts they had learned in lecture and in the sessions to the question on the test. Part c of the question was again very much like one of the topics covered in question two of the session. In this case students were shown a variety of different ways to solve for the velocity when given the work. Many of the students who went to the session were able to gain ten out of ten points on this portion of the question. The two who were not able to do this were docked points for errors in the previous parts or in one case the student used the wrong method. Since most students were able to gain thirty our of a possible thirty points on this particular question, one can conclude that the session helped the students to understand the concepts more fully. One can also conclude that once given the information students are able to adapt the information to fit different problems that use the same concepts extremely well.

The second question asked students:

> A 20kg object at rest on a frictionless horizontal plane is struck by a 10kg object traveling to the right at 9 $^{m}/_{s}$. After being struck, the 20kg object slides to the right with a speed of 5 $^{m}/_{s}$. a) Determine the speed and direction of motion of the 10kg object after its impact with the 20kg object. b) Following the impact, the 20kg object then slides over a 2m rough spot on the floor (where μ=.3), then back onto a frictionless surface where it encounters and begins compressing a spring of k=600 $^{N}/_{m}$. Determine the spring compression distance required to bring the 20kg object momentarily to rest.

This question was similar to the third question asked in the problem session, although springs were not covered on that particular day. Part a, was a simple collision problem, while it was very similar to the third question asked in the problem session, students had to take into account the force of friction as well. Many of the students who came to the session were able to receive at least eight out of ten points, with the exception of one student who did not get any points. This student did not seem to understand what the question was asking since there was an answer; it was just not the answer to the question. Many of the students who lost one or two points lost them for directional issues, which are very small errors, instead of a conceptual problem.

The second part of the question was again a collision, but students needed to do this part in sections instead of all in one. First the students needed to calculate the speed the block hit the spring with, which includes one calculation for the rough spot and one calculation for the smooth spot. Then the collision including the spring constant and then the recoil. Many of the students were able to get at least six out of ten points on this particular portion, although some were not as able to answer the question. In the problem session the students quickly reviewed how a spring constant would be worked into a problem but it was never directly brought up as an actual problem. The students who lost two points made small errors in their calculations, while the students who lost up to four points did not separate the problem into multiple parts. While there is a way to do this all in one, it is much easier to do this portion in parts. The students who received two or less points on the second portion did not answer the correct question. They seemed confused by the concepts this time, and did not think to break up the picture into sections and solve it separately. In this case it seems that students would have benefited from one very complicated question instead of a couple of one topic questions. As stated above it is difficult to cover every topic during movies because students have only so much attention and stamina, also movies may cover a great deal of topics but not every one that will be on the test. Many of the problem sessions were right on topic, but it seems this test deviated slightly from the sessions that were run.

The third questions asked students:

> Masses m_A and m_B sliding across a frictionless horizontal xy plane collide with each other at the origin, stick together, and travel together with the same final velocity $v_f = (5\mathbf{i}+4\mathbf{j})\ ^m/_s$. Before the collision, m_A has $v_A = 8\mathbf{i}\ ^m/_s$. a) Calculate the before-collision velocity of m_B. b) Calculate the impulse received by m_B during the collision. c) The duration of the collision is .2s. Determine the magnitude of the average force acting on m_B during the collision. On the axes at right, sketch an arrow representing the direction of average force and determine a numerical value for the angular direction measured from the axis of your choice. d) Calculate the total work done on m_A during the collision. e) Determine the magnitude and direction of the impulse received by m_A during the collision.

This particular question was extremely similar to the second and third problems during the problem session. In this case many of the students had dealt with portion a in many tests and homework problems previous to this test, it was a simple mechanics problem. The second portion of the problem was very similar to questions asked on the second test and one problem addressed in the problem session. In this case again students had a lot of practice with the second portion as well. The third portion of the question was a slightly inelastic collision so a combination of problem two and problem three. Students had less practice combining the two but were shown both ways in the problem session. The fourth portion of this question was covered in problem one. The fifth portion of the problem was again covered in problems two and three in the problem session. While students were only asked to evaluate one body in the two problems in the review session it is an easy transition from evaluating one body to evaluating two.

Many of the students were able to receive at lease eight out of ten points on this particular question. The points lost were for style and minor calculation errors. Those that lost more than two points on this question either used the wrong equation or forgot that velocity was a vector quantity. In this case it shows that students did not truly understand the concepts from tests previous to the third one. Unfortunately students who did not understand concepts already tested in examinations previous may not have received the full effect of the problem solving session, because these sessions assumed that students had learned the concepts tested on previous tests, which may have been an incorrect assumption. The second portion of the question was very much the same case as the first, impulse questions had been asked on tests previous. Many of the students were able to earn at least seven out of ten points on this particular question. The one student who was not able to get any points on this question had made a mistake in the previous problem and not treated the velocity as a vector.

In the third portion of the question students had been given a lot of practice drawing force diagrams and then creating the equations from those particular diagrams. Most students were able to gain at least six of ten points on this particular question. The errors that were made were mostly situations where students failed to answer the entire question. Looking at the problem it seems as if students were easily led to the conclusion that they were only supposed to draw a diagram when in fact they were supposed to draw a diagram, give the magnitude and angel, and then give the answer in components. The students who lost more than four points on this question made the same errors as the students above and also were confused about the direction the object was moving. In this case most of the students understood the concept while a couple were not clear on how to determine the direction. Unfortunately the students had been warned about the tricky nature of angles and how one must determine the quadrant of the angle before drawing the direction.

The fourth portion of the question was extremely similar to the second portion of questions one and two in the problem solving session. In this case students had practice calculating the work, not on a collision problem, but on an inclined plane problem. Question number one gave the students the task of finding the work done over the five meter movement and then had to find the final velocity after the five meter movement using the work equation. Many of the students were able to earn eight out of ten points on this particular questions. The points lost were for bad math or style errors. The students who lost more than two points on the question used the wrong numbers or did not remember that velocity was a vector quantity and then subsequently could not determine what the correct work calculation. This particular student lost a great number of points on many questions because of the oversight concerning velocity.

6.0 Conclusion

Through my experiences in the introductory physics classes, including Mechanics, Electricity and Magnetism, Quantum Physics and Relativity, and Waves and Oscillations, I have found the professors are often very informative, but the way in which they present the information is sometimes hard to understand. The information presented is not too hard to comprehend or are poorly presented, but that I had a very hard time relating the physics to anything I could see. Many of the examples are easy to visualize, but since the physics is so disconnected from what people perceive as the physical world it was hard to understand the actions and how they relate to the concepts.

The mathematics was also very intimidating. While Worcester Polytechnic Institute's regular series of physics classes only use algebra to describe the actions the quantity of equations and the manipulations that one needs to perform to completely understand what is going on is very frightening. As a freshman in college many people, such as myself, are frightened by the classes themselves along with the content because it has always been viewed as a higher educational experience.

While talking to some professors during my academic career I have realized the problem that students and professors are having, it is in their communication. As Fred Hudson said

> Many of us grew up listening to the radio and having to draw pictures of situations in our heads. Listening to a lecture is much more comfortable for me because I have been taught to gather information from hearing it. Students now have grown up watching television and using the computer. They are used to gathering information visually and it is very hard for students today to gather information from a lecture because they don't see what is going on.

This statement is very telling of the hard time students and professors are having communicating. Movies are the first steps in helping professors to teach in a more visual manner, and to helping students learn how to gather information from a lecture. Since students have to apply concepts to the situation in the movie, they must first gather the information from the lecture and the picture is completed by seeing a real-time example. As seen in the background information studies have shown that students do not react well to a traditional lecture situation. It is very important to get students to participate and interact with the concepts being presented so they have a clear understanding of the information they are learning. When this example comes in the form of Hollywood movies, books, or comics students become more interested in the material because it has captured their attention. Not only do they see what is going on and what an action should look like, they are interested to see what else the physics can apply to. In using a medium that students are already interested in one can transfer that enthusiasm to the subject she is teaching by relating the examples to this medium.

The reason I used movies to help students was how the visual aspect helps to make the physics seem less intimidating. When students see that it is possible to apply the physics to something as fun as a movie they immediately disregard their fears and are able to perform the manipulations required to understand the concepts. The visual aspect of movies also helps students to be able to see what is going on in the problem. Instead of drawing free body diagrams and sketching the motion students see exactly what is happening and all of the motions performed in real-time. This just serves to bring the information closer to the students. As someone who has had a fair amount of trouble visualizing and applying the physics I was taught in my freshmen year of college I feel that if students are given a better visualization they will be able to better understand the problem. The students who came to the sessions also felt this way. As seen above, many students answered that seeing the movie and then applying the physics helped them to visualize the situation given on the test.

While this project was very successful there were some setbacks. One of the largest problems I had was getting the students to fill out the survey. Not knowing the trouble some professors have in getting students to fill out surveys I emailed it out and trusted the students to return it. Unfortunately many of the students did not, thus I did not get as much feedback as I would have liked.

Also many of the students did not stay for the whole session. They would wait until the problem solving was done and then leave, which ultimately did not affect their physics grades but did indicate they were particularly interested in watching the rest of the movie. My conclusion from their actions and the survey responses is: they were interested in getting the context of the problem from the movie but were there primarily to get some help with the physics. Since the group was self selected it indicates that they came because they needed help. So their early departure would be congruent with their ultimate goal of gaining a better understanding of the physics.

The last large problem I had was getting students to turn in the extra assignment they were given. One of the important portions of this experience, I believe, was getting students to pick out examples for themselves and explain the concepts used in that situation. For example students could have picked a scene in the Matrix where Trinity hung in the air after jumping.

Explaining the conceptual flaws with this scene is very easy, but forces students to think while watching the movie, not just letting their brains lay dormant. Since this particular assignment did not affect their grades a lot of students did not complete it, so that particular portion of the experiment was eliminated by the student's unwillingness to participate. If I were to do these sessions over again I would give a small amount of credit for each assignment so that the students felt it was necessary to complete.

While this particular experiment was used for teaching physics classes, the technique can be used on a wide range of subjects. Anything that uses problems that relate to real life would be conducive to this method. Since many students have a large problem visualizing concepts when they are not directly related to real life; the extra visual example would help all students to have a better understanding of the particular subject matter. As seen in the background section, one professor has taken this concept a step farther and teaches general science to middle scholars through books, movies, and televisions shows.

Many of the students who participated in this experiment felt all the goals were reached. In analyzing the tests students took, they were performed well on the questions directly related to those done in the problem solving session. One may conclude that the information was just fresh in the students mind, but during lecture and conferences students see each type of problem at least ten times each, giving them a clear view of what will be on the test, and how these problems work. Yet some students still cannot grasp the basic concepts presented. The questions given on the test are also of the same type given in class. The hypothesis of this experiment was, if students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented. Since the problems presented during the problem sessions were the same as those given in lectures and tests the only difference in material was the presentation. In using exceedingly different methods of presentation I was able to catch the students' attention. Consequently, from the first moments of the session the students were already paying attention and ready to learn.

Surveys

These surveys were given to students
at the end of all of the problem solving sessions.
Many of the students chose to fill them out,
although some were unable to assist in this matter.

Media Physics

Name: Class:

Number of Sessions Attended: Year:

1. Did you find the problem solving sessions helpful? Why?

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?

4. Did you feel more or less prepared for the exam after the problem solving session? Why?

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?

8. Would it have been more helpful to have done individual clips during the session? Why?

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?

10. The hypothesis for this IQP was:
    If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
    Do you think this goal was achieved? Please explain.

Media Physics

Name: Student 1

Number of Sessions Attended: 1

Class: PH1110 Section04

Year: 2006

1. Did you find the problem solving sessions helpful? Why?

I found the sessions helpful. It was easier to get the concepts with a smaller group of students and a more informal approach to learning.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?

The most helpful aspects were a smaller group and seeing the concepts in real life situations. I didn't really find anything that was not helpful.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?

I think that the session improved my performance on the exam by giving me a better understanding of the material and also just having more prblems to practice on.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?

I felt more prepared for the exam after the session because I felt that I had more experience with the problems and also I had a clearer understanding of what was going to be on the exam.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?

I think the examples in the movie did connect to the concepts taught in class. It was easier to understand the concepts when I could see them in a realistic situation.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?

I think the problems given in the session were helpful to immediate course work, they related directly to the homework and to the problems on the exam. I could relate to the problems to the movie rather easily, mostly because of their relevance to the scene that had just taken place.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?

I liked the immediate stop of the movie to work on a problem. It made sure that the events in the scene were fresh in your mind so that you could relate them to the given problem. I would have forgotten some scenes if the whole movie was watched first and then the problems were presented.

8. Would it have been more helpful to have done individual clips during the session? Why?

I don't think that would have been any better, I pay more attention to a movie with a continuing story than to separate clips that are unrelated.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?

It interested me more in the material because I could see that the course material actually has real world use. I find it helpful to apply the concepts in class to actual life.

10. The hypothesis for this IQP was:
If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented. Do you think this goal was achieved? Please explain.

I think this goal has been achieved. I respond better to a relaxed learning environment. The movie helped make the session fun and interesting and with that the material was easier to comprehend.

Media Physics
Name: Student 2 Class: 05
Number of Sessions Attended: 1 Year:

1. Did you find the problem solving sessions helpful? Why?

   They were helpful because they reinforced topics brought up in class.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?
   Most helpful, see above. Least helpful; some topics talked about were stretches of what was in the movie.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?
   It did not hurt on the exam, but it did not help either, because it was mostly review

4. Did you feel more or less prepared for the exam after the problem solving session? Why?
   yes, but that was due to lecture and conference being productive

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?
   sometimes yes, sometimes was a stretch

   \

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?

   helpful in terms of review, but I can see how if understanding of material was fuzzy that it would be confusing

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?

   IT didn't really matter either way

8. Would it have been more helpful to have done individual clips during the session? Why?
   For in terms of just reviewing physics, yes

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?

   did not help or deter, because the physics is not in my general interest anyways

10. The hypothesis for this IQP was:
    If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
    Do you think this goal was achieved? Please explain.

If a student is interested in physics in the first place, yes.
If a student is not really interested in physics, no.

Media Physics
Student 3 Class: Year:2006
attended 3 or so i think

1. Did you find the problem solving sessions helpful? Why?

   Yes, it helped reinforce many of the main ideas that were taught to us.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?

   Solving different types of problems

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?

   Yes i believe that it helped me. We went over similar problems and concepts that appeared on tests.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?

   Isnt this question pretty much the same as number 3?
   well here it is again:
   Yes i believe that it helped me. We went over similar problems and concepts that appeared on tests.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?

   Yes some examples were a better visual aid, and were easier to remember when taking the exam. Yes the examples matched the concepts we were learning in class.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?

   I guess it helped with the immediate coursework as well too. Some problems were easier to relate to then others.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?

   The stop and start did not hinder my concentration. I liked having the option of watching the whole movie or not to.

8. Would it have been more helpful to have done individual clips during the session? Why?

   If it makes for a better example to what we are trying to learn, then maybe.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?

   No, it didnt really stimilate my interest in the course material. Physics is still physics, a movie can not change that. But it did help present it in a more interesting way.

10. The hypothesis for this IQP was:
    If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
    Do you think this goal was achieved? Please explain.

Yes I think the goal was achieved, the sessions helped make the couse material a little bit more interesting and enjoyable.

Media Physics
Name: Student 4
Number of Sessions Attended: 1

Class: PH 1110
Year: 2006

1. Did you find the problem solving sessions helpful? Why?
   Yes I did. The one session I attended addressed the major problem areas of the final exam in PH1110 term C 2002-2003.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?
   The most helpful aspect of the problem solving was that we were made to participate at the black board. The least helpful aspect was the questions tended to be short and only deal with one issue at a time. The problems on the tests incorporated more than the session problems did, but that's mainly because the test problems were tailored and session problems were found.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?
   I don't think it did much for me personally. By that time I had already done the practice exam and the extra homework problems. Had the session been held earlier it might have helped more. But I'm confident that I went into the session, already knowing most of the principles.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?
   More prepared. It helped solidify the terms and procedures in my mind. I was made to participate, unlike lecture; I was paying more attention.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?
   The visual aid was there, but it also wasn't very believable. I've never had a problem visualizing a problem before, so that advantage was wasted on me.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?
   Yes, the questions were well chosen to represent the current lecture, such as rotational motion. However due to the nature of the lecture (which included: downward acceleration, tangential acceleration, apparent weight) it is very difficult to find questions in popular films that address all of these issues.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?
I stayed until almost the very end, because I liked the movie. I only left after I realized what time it was. The only real hindrance to the movie was that the lights were on the entire time. But it provided for a much more relaxed environment and actually coaxed me into attending. There was a double-edged sword, though, in that we did not know in advance which movie would be shown. Having to sit through a movie I hated and do physics problems was almost enough to keep me from attending.

8. Would it have been more helpful to have done individual clips during the session? Why?
If you mean fast forwarding to the parts of interest to physics, no it would not have been helpful. While it would expedite the process of teaching us the material, it would ruin the movie. Without the movie, all we are doing is attending a physics lecture late at night.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?
It helped a lot not only as a method for getting me to attend but also for grabbing my attention.

10. The hypothesis for this IQP was:
If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
Do you think this goal was achieved? Please explain.
Yes. While the material was presented in a fun manner, the immersion of the movie is ruined by stopping mid-scene to discuss a physics equation. However, this fact cannot be avoided. If you provide the examples before hand then it would be lost on someone who has never seen the film. If you provide the equations afterwards then it would require much more of a time commitment and the willingness to learn wouldn't be there. At least for me, there was almost a drive to finish the physics problem quickly and accurately so that the movie would be allowed to continue. It was certainly a better experience then a one hour lecture.

Media Physics
Name: Student 5 Class: PH1010
Number of Sessions Attended: 1 Year: (Senior)

1. Did you find the problem solving sessions helpful? Why?

Somewhat. The visual medium, however, did not synch properly with the material covered, in my opinion.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?

The discussion of the problem would likely take the place of most important, while least would go to the actual development of the problems from the medium – which was, as I understood it, the point of the IQP. In the session I went to, I simply was not experiencing the movie and the understanding of physics on the same level. Rather, it was more as if I was watching a movie (I had seen before) with a few semi-related physics questions interjected here and there.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?

I do not believe the influence was very great.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?

Neither. For previously mentioned reasons.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?

Again, I do not feel it did. In respect to 'why,' this is perhaps due to the movie itself. "Rush Hour" may not have been the best choice of material. An easier thing to do would be to rent out a scifi movie (you'd have drawn in the scifi crowd, too) and point out all the violations of physics and physical impossibilities that occur.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?

No, and sadly: no.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?

My concentration was not affected.

8. Would it have been more helpful to have done individual clips during the session? Why?

In a choice between individual clips and a streaming, whole movie, I would support the latter. Watching disjointed clips of things is more disorienting, and less interesting, overall.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?

I'm an engineer. I don't like 'true' physics, especially given my… prior experiences here at WPI. There was NOTHING you could have done that was not tried already, and that had previously failed to stimulate my interest in physics.

10. The hypothesis for this IQP was:
If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
Do you think this goal was achieved? Please explain.

I think… Hmm. 'Receptive to the information presented.' I cannot say for others, but for myself, this was obviously not achieved. Perhaps in the other sessions it went off more smoothly, in truth I cannot say. If you were to ask: 'can' this goal be achieved, I would say "yes, it is possible." Was it, however. That, I cannot affirm with any certainty.

Media Physics
Name: Student 6 Class: Koleci sect 5
Number of Sessions Attended: 3 Year: 2006

1. Did you find the problem solving sessions helpful? Why?

   Yes the problems were a great way to encorporate physics with daily life. Also, it was good to practice problems before the exam when a lot of people wouldn't study that far ahead of the exam.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?

   The most helpful aspects was doing problems relating to the tests or what we were doing in class. The one that I learned the most from was where we had to derive the formulas as we were not given any numbers for the equations. Least helpful was probably doing the writeup, if it were shorter it would've been easier.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?

   I think the session helped my grade as it helped me study earlier. I did better on the exams where I went to these sessions because I put more time into physics.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?

   I felt more prepared for the exam as we did similar problems to those that would be asked on the test.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?

   Yes the examples related to class problems and allowed us to connect it to both a movie and a certain situation. So then on the test I was able to remember the instance in the movie to remember how we did the problem.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?

   The problems were helpful and easy to relate to the movie and current classwork.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?

   It was helpful to stop and watch the movie so you remember that physics really is related, otherwise we would've gotten too absorbed in the movie.

8. Would it have been more helpful to have done individual clips during the session? Why?

   No I liked the idea of the whole movie to watch since u can see more than 1 instance physics can relate to it. Also, the movies chosen to be watched were enjoyable so it was a great way to watch a film and do work at the same time.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?

   The usage of movies helped my interest in physics as they are enjoyable films and good to see how it relates to life. If you had just stood up there and did the same problems without the movie, it would not have been the same interest.

10. The hypothesis for this IQP was:
    If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
    Do you think this goal was achieved? Please explain.

    Yes, it was much easier to be enthusiastic and pay attention to the problems in a fun setting rather than just sitting and copying down notes. Also, it was fun because it was a smaller group of students compared to our huge class so it was more individualized and easier to stay focused.

Media Physics
Name: Student 7 Class: 2006
Number of Sessions Attended: 1 Year: 1st

1. Did you find the problem solving sessions helpful? Why?
   Yes it was pretty helpful because it helped me to further understand the material we were covering in PH1110 at the time.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?
   Relating the problems to the movies made it a bit easier to pick up on how the problem worked and made it easier for me to remember. The least helpful fact was that it was three hours long, but that's understandable since we do get to watch a movie too.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?
   I believe it helped me do a little bit better than I would have without the session. Reviewing the problems the night before the exam is definitely a huge help besides studying.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?
   I felt more prepared for the exam because of the extra help I got.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?
   Yes, because I could remember the way to solve problems a bit easier by thinking about the movie.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?
   Yes the examples in the movie were easy for me to relate to the problems during the session.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?
   The constant stops and starts only made me forget what happened earlier on in the movie so I couldn't follow the plot as well. But I feel it was better to do the examples right after they happened in the movie because then it was fresh in your mind.

8. Would it have been more helpful to have done individual clips during the session? Why?
   Individual clips probably would have been better to use because then you wouldn't have to search through the movie to find them and you can go in a specific order to teach the

material in the order you wanted to.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?
   It made physics a lot more fun by using a movie to display them in action.

10. The hypothesis for this IQP was:
    If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
    Do you think this goal was achieved? Please explain.
    Yes, I think the goal was pretty much achieved because it definitely got me more interested in topics we discussed. Visual aids, like the movie, help me to learn a lot better.

Media Physics
Name: Student 8 Class:Freshman
Number of Sessions Attended:1 Year:2006

1. Did you find the problem solving sessions helpful? Why?
YES BECAUSE IT GAVE GOOD PRACTICE FOR THE PROBLEMS ON THE TEST.

2. What was the most helpful aspect(s) of the problem solving sessions? What was the least helpful aspect(s) of the problem solving sessions?
DOING PRACTICE PROBLEMS WAS THE MOST HELPFUL PART. THE LEAST HELPFUL PART WAS DOING PROBLEMS THAT WOULD NOT BE ON THE TEST.

3. Do you think that the problem solving session influenced your performance on the exam? Overall? Why?
I THINK I DID MUCH BETTER ON THE TEST BECAUSE OF THE PROBLEM SOLVING SESSIONS BECAUSE I REALLY LEARNED A LOT AND UNDERSTOOD IT MUCH MORE.

4. Did you feel more or less prepared for the exam after the problem solving session? Why?
I FELT MUCH MORE PREPARED BECAUSE THE PROBLEMS WERE EXPLAINED VERY WELL AND WE COVERED EVERY PART OF THE PROBLEM SO I COULD FIND MY MISTAKES.

5. Did the examples in the movies connect to the concepts taught in class? Did it help to create a better visual aid for that genre of problem? Why?
I ESPECIALLY APPRECIATED THE EXAMPLES IN THE MOVIES BECAUSE IT GAVE REAL LIFE EXAMPLES OF THESE PROBLEMS AND THAT HELPED ME UNDERSTAND THEM BETTER.

6. Were the problems given in the session helpful to the immediate course work? Were the examples in the movie easy for you to relate to the problems given during the session?
I WOULD SAY THAT I PROBABLY HAD TO STUDY LESS BECAUSE I BELIEVE I UNDERSTOOD WHAT WAS GOING ON AFTER THE SESSIONS. I DID NOT HAVE TO GO HOME AND FIGURE EVERYTHING OUT FOR MYSELF WHEN STUDYING.

7. Was it helpful to have the option of watching the whole movie or did the constant stop and start hinder your concentration?
   I DIDN'T MIND THE STOP AND START BECAUSE IT WAS DEFINITELY NECESSARY TO UNDERSTAND THE PROBLEMS.

8. Would it have been more helpful to have done individual clips during the session? Why?
   NO THAT WOULD HAVE BEEN ANNOYING IF THERE WASN'T A STORYLINE BEHIND IT.

9. Did relating physics to popular media stimulate your interest in the course material? Did it deter you? Why?
   IT STIMULATED MY INTEREST IN THE COURSE MATERIAL BECAUSE I SAW HOW IT COULD BE APPLIED IN REAL LIFE.

10. The hypothesis for this IQP was:
    If students are shown physics problems and asked to identify concepts learned in lectures in an interesting, relaxed, and fun manner they will be more receptive to the information presented.
    Do you think this goal was achieved? Please explain.

I THINK YOU DEFINITELY ACHIEVED THIS GOAL BECAUSE FOR THE SESSION I WAS AT, I DID VERY WELL ON THE TEST TWO DAYS LATER BECAUSE I TRULY UNDERSTOOD IT.

Charts

This section is filled with charts to give a visual analysis of the scores students received on a pre and post test given at the beginning and end of the physics 1110 class.

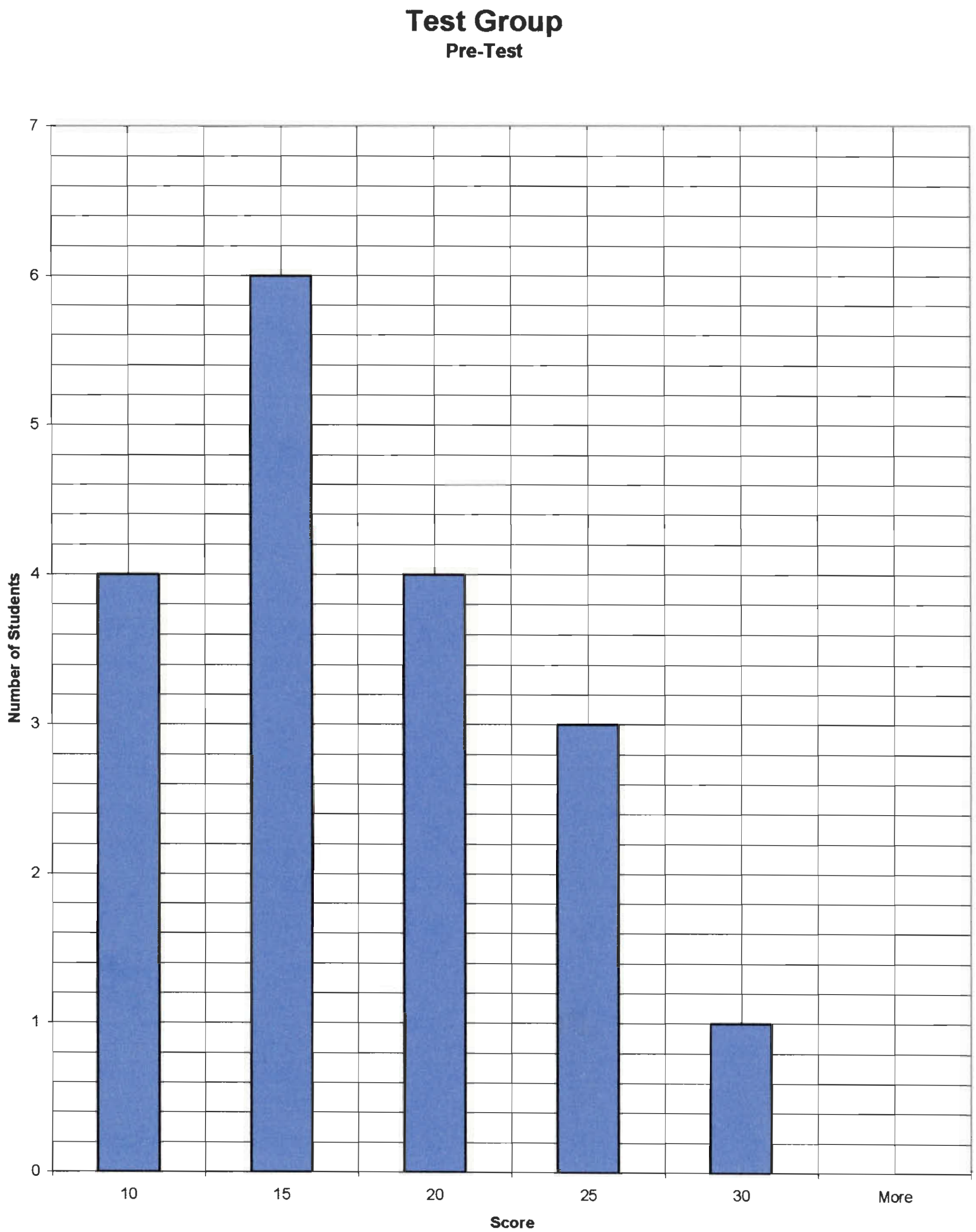
Pre and Post Test Scores from Test Group

	Pre-Test	Post-Test	Difference
Student 1	16	28	12
Student 2	7	12	5
Student 3	21	24	3
Student 4	13	19	6
Student 5	13	17	4
Student 6	8	14	6
Student 7	26	20	-6
Student 8	15	18	3
Student 9	8	10	2
Student 10	8	9	1
Student 11	11	18	7
Student 12	19	28	9
Student 13	11	8	-3
Student 14	23	28	5
Student 15	21	22	1
Student 16	14	17	3
Student 17	20	18	-2
Student 18	18	16	-2
Average	15.11	18.11	3

Pre and Post Test Scores from Entire Class

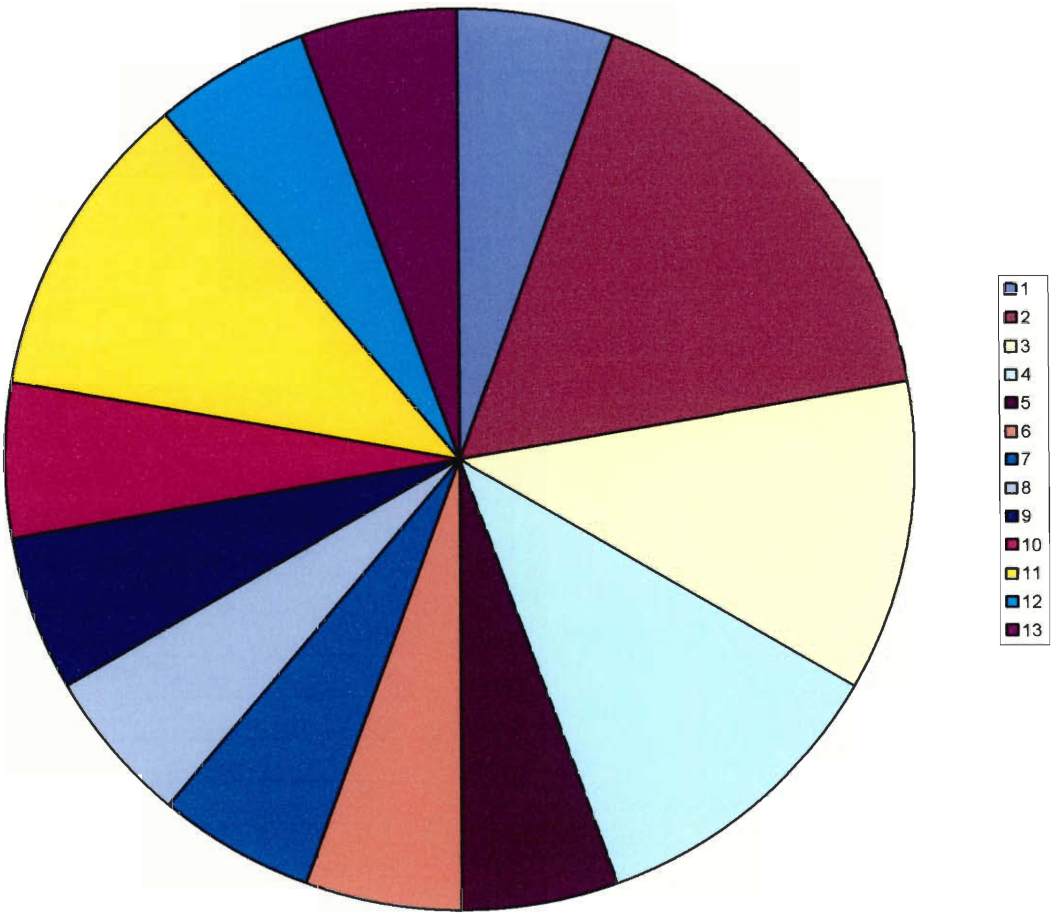
	Pre-Test	Post- Test	Difference
Student 1	16	28	12
Student 2	7	12	5
Student 4	13	19	6
Student 5	13	17	4
Student 7	26	20	-6
Student 8	15	18	3
Student 9	8	10	2
Student 10	8	9	1
Student 11	11	18	7
Student 12	19	28	9
Student 13	11	8	-3
Student 14	23	28	5
Student 15	21	22	1
Student 16	14	17	3
Student 17	20	18	-2
Student 18	18	16	-2
Student 19	21	24	3
Studetn 20	20	23	3
Student 21	11	20	9
Student 22	20	22	2
Student 23	27	29	2
Student 24	23	22	-1
Student 25	15	16	1
Student 26	10	10	0
Student 27	11	13	2
Student 28	16	25	9
Student 29	23	25	2
Student 30	8	14	6
Student 31	17	19	2
Student 32	20	20	0
Student 33	16	22	6
Student 34	19	20	1
Student 35	11	18	7
Student 36	10	10	0
Student 37	14	16	2

	Pre-Test	Post- Test	Difference
Student 38	28	28	0
Student 39	16	15	-1
Student 40	25	30	5
Student 41	24	30	6
Student 42	13	21	8
Student 43	5	9	4
Student 44	20	25	5
Student 45	18	23	5
Student 46	17	23	6
Student 47	18	19	1
Student 48	10	8	-2
Student 49	16	19	3
Student 50	25	26	1
Student 51	4	12	8
Student 52	12	14	2
Student 53	14	19	5
Student 54	16	17	1
Student 55	16	27	11
Student 56	18	19	1
Student 57	22	28	6
Student 58	6	18	12
Student 59	19	24	5
Student 60	15	28	13
Student 61	12	15	3
Student 62	23	27	4
Student 63	23	23	0
Student 64	8	9	1
Student 65	20	28	8
Student 66	21	21	0
Student 67	16	19	3
Student 68	11	10	-1
Student 69	15	21	6
Student 70	15	22	7
Student 71	19	13	-6
Average	16.3	19.49	3.19


Test Group
Pre-Test
Number of Students
0
1
2
3
4
5
6
7
10
15
20
25
30
More
Score

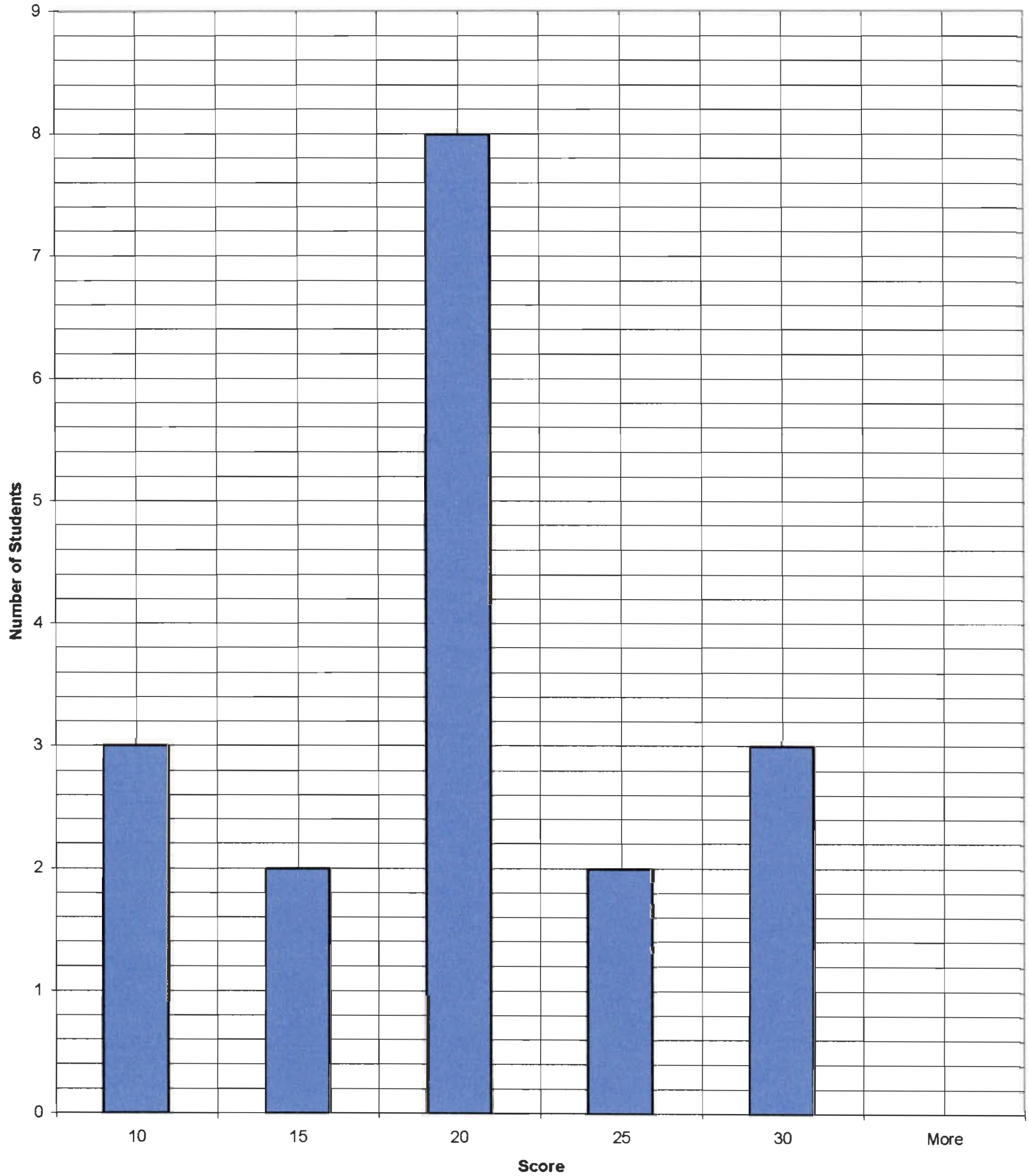
Test Group

Pre-Test



Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Score	7	8	11	13	14	15	16	18	19	20	21	23	26
Percentage	5.6%	16.7%	11.1%	11.1%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	11.1%	5.6%	5.6%

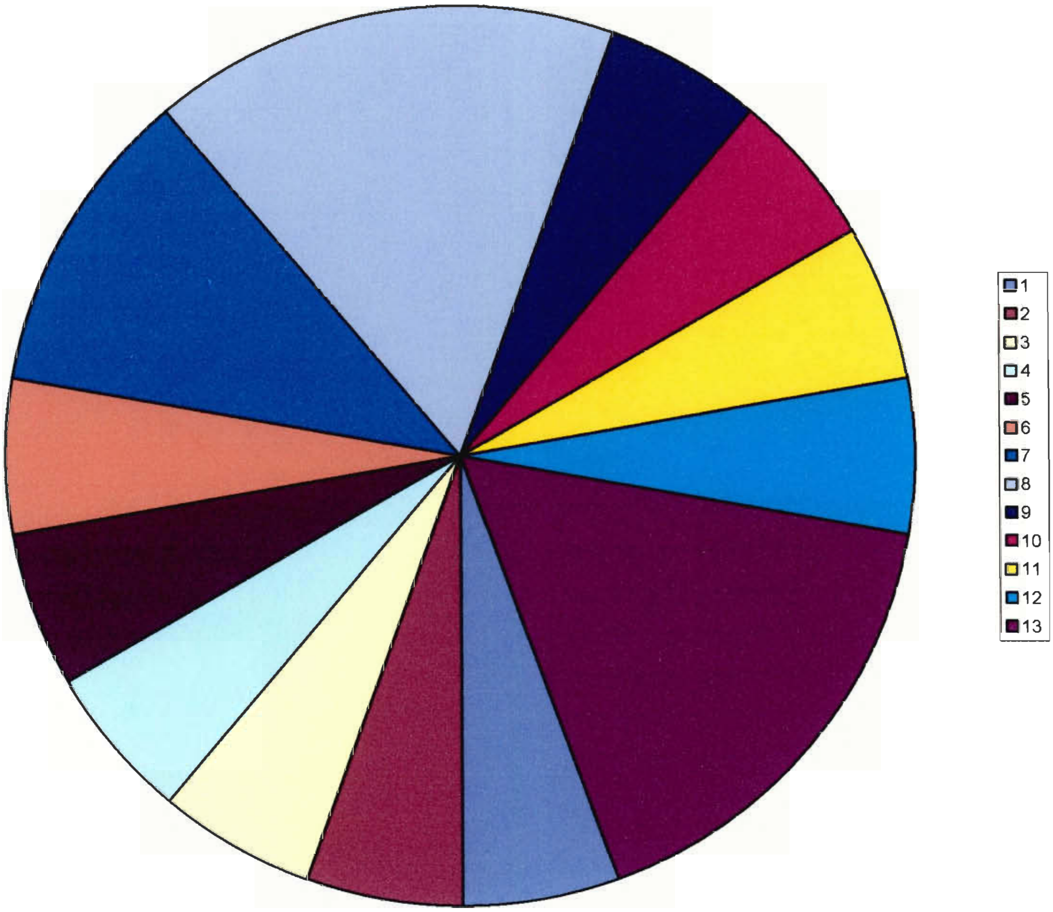
Test Group
Post-Test



Appendix B

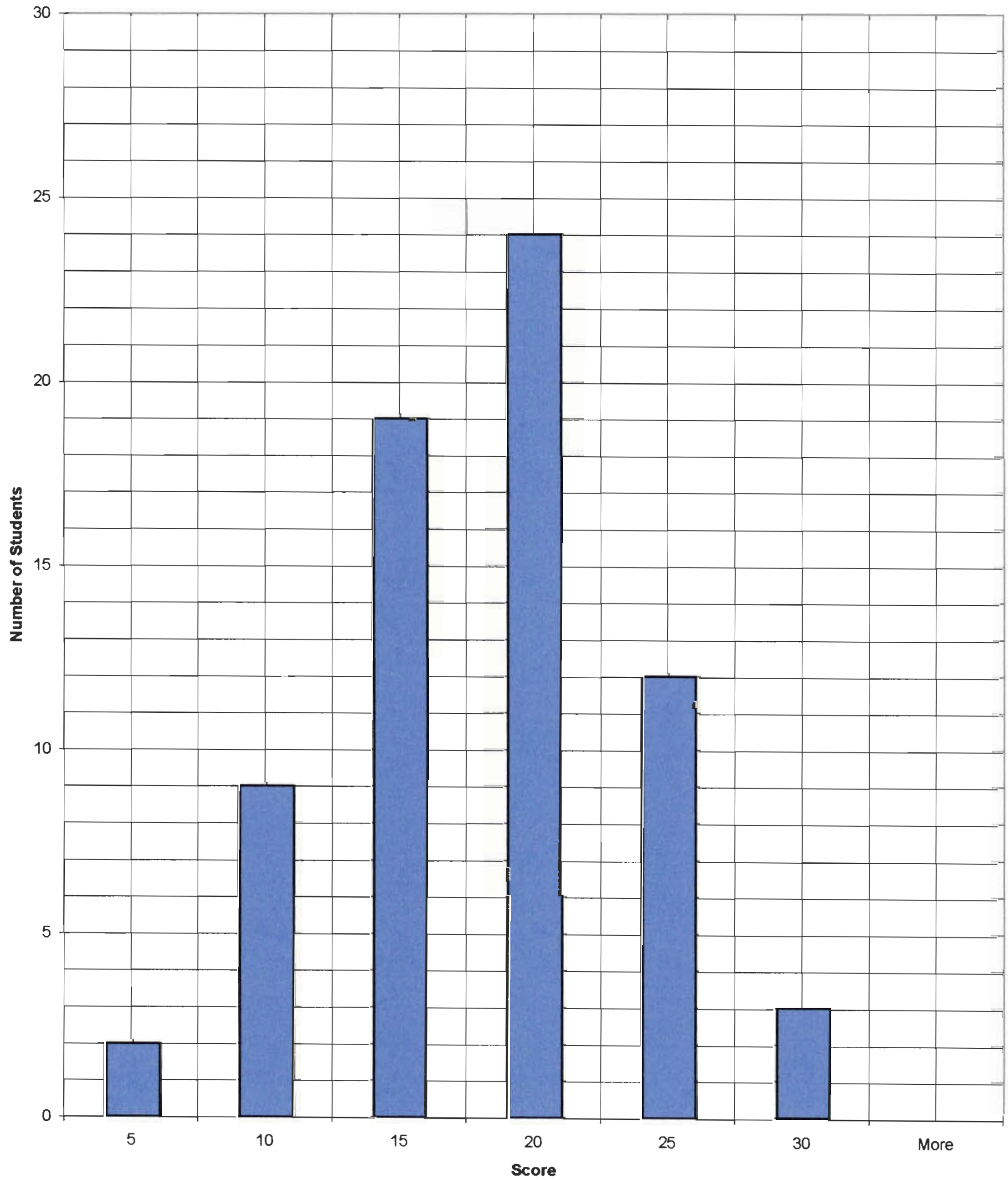
Test Group

Post-Test

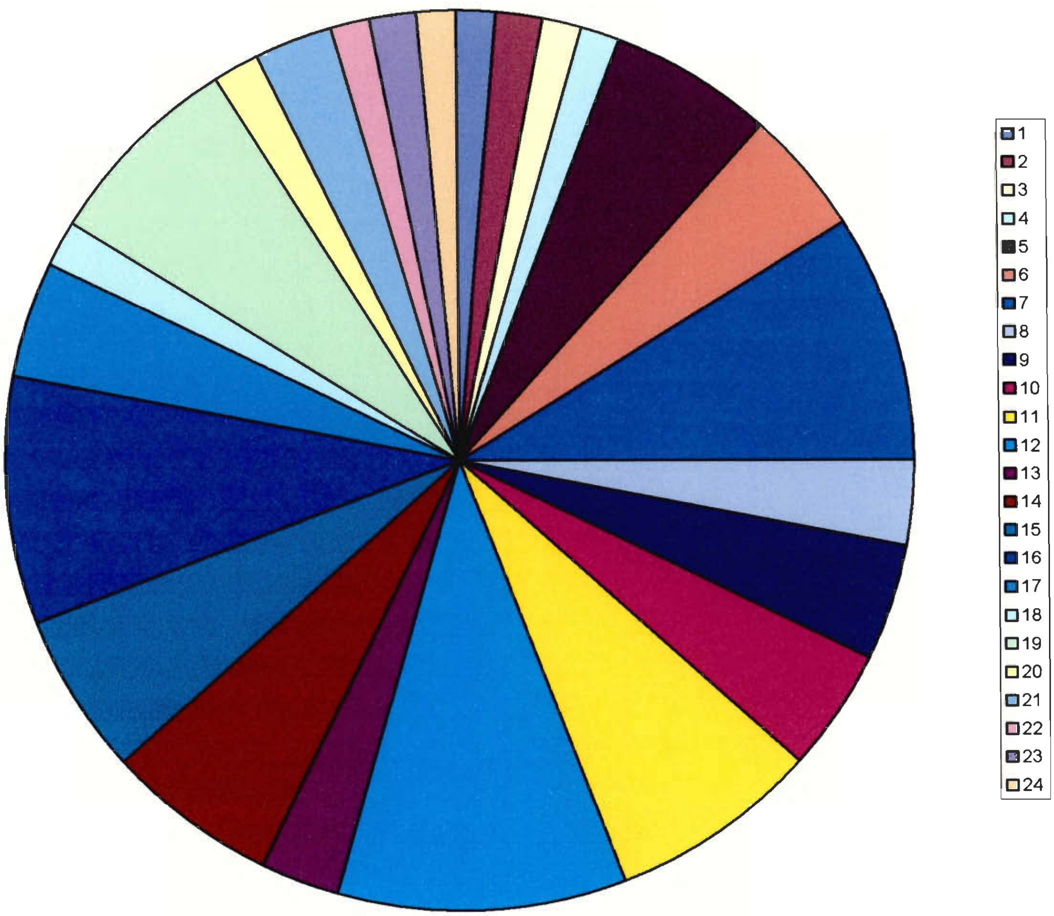


Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Score	8	9	10	12	14	16	17	18	19	20	22	24	28
Percentage	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	11.1%	16.7%	5.6%	5.6%	5.6%	16.7%

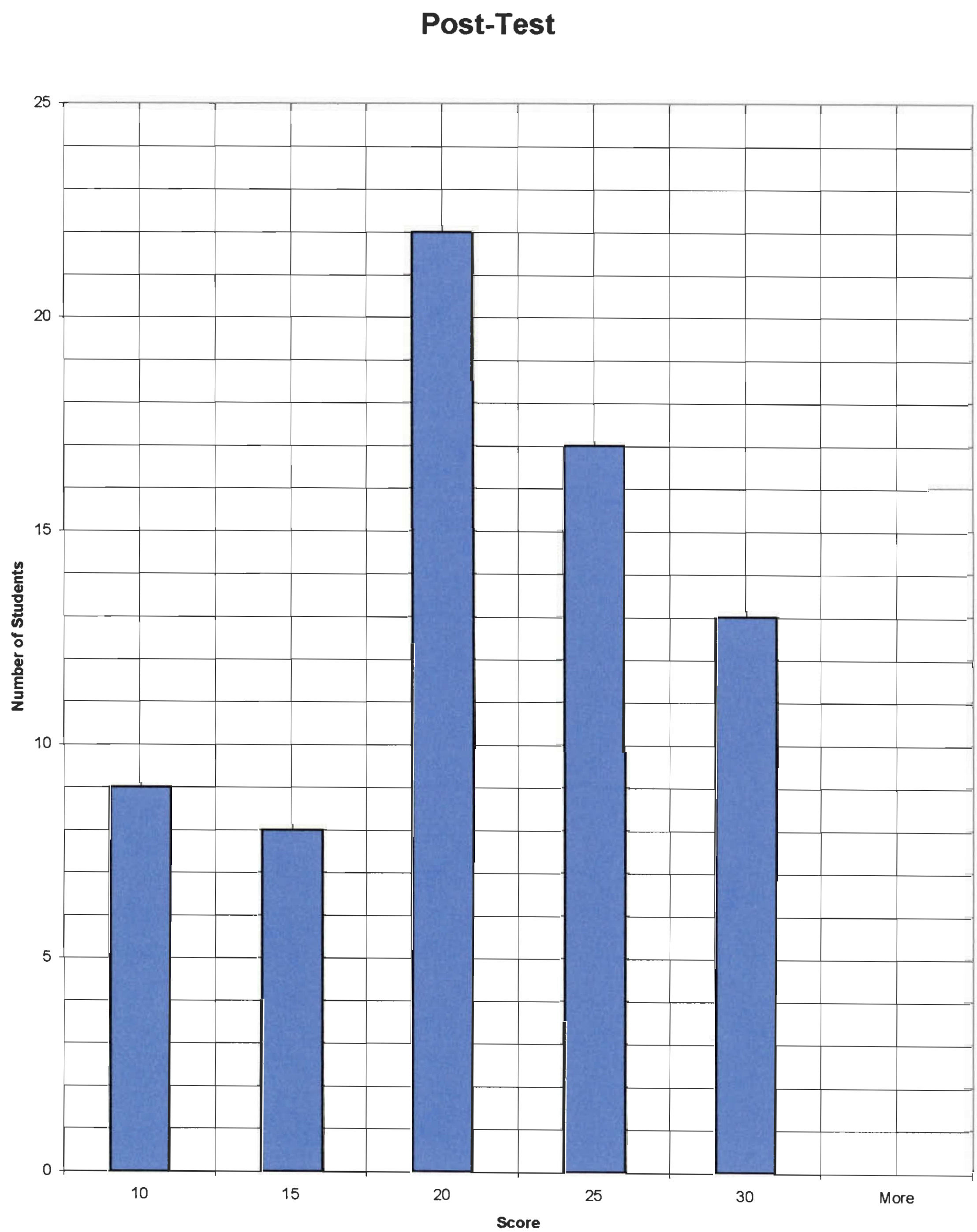
Pre-Test



Pre-Test

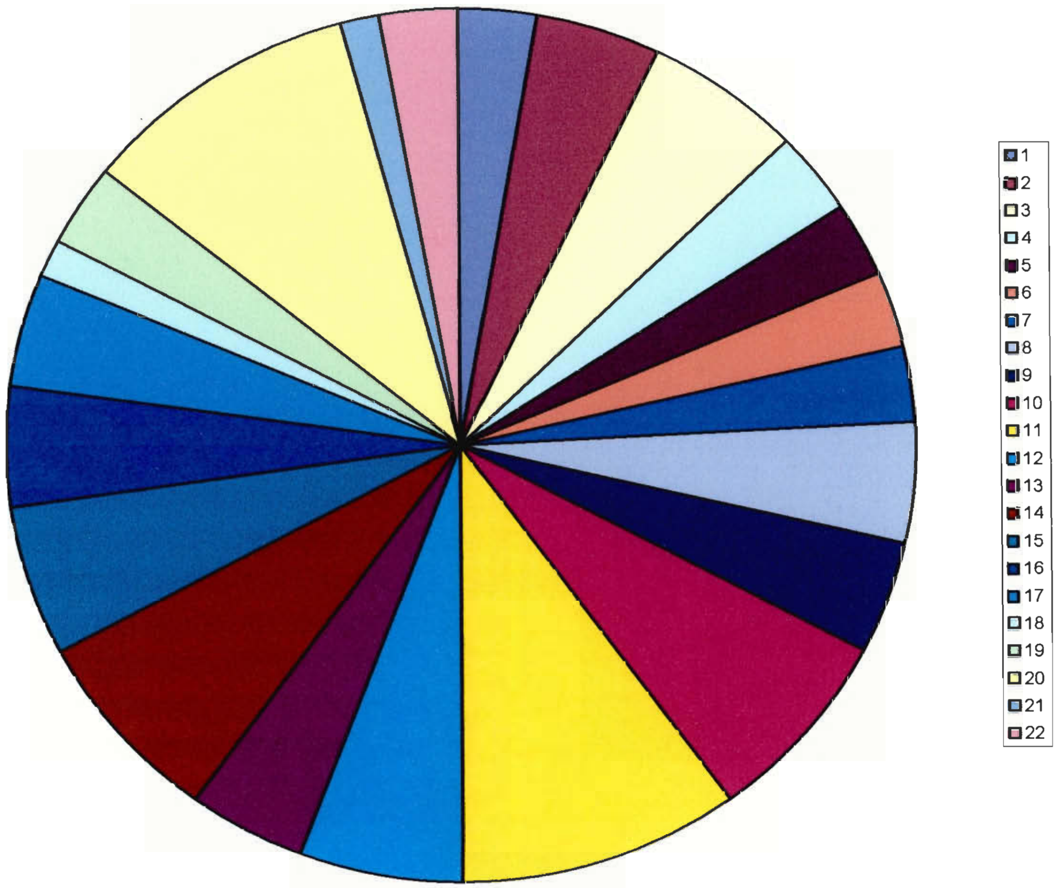


Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Score	4	5	6	7	8	10	11	12	13	14	15	16	17
Percentage	1.4%	1.4%	1.4%	1.4%	5.8%	4.3%	8.7%	2.9%	4.3%	4.3%	7.2%	11.6%	2.9%
Number	14	15	16	17	18	19	20	21	22	23	24		
Score	18	19	20	21	22	23	24	25	26	27	28		
Percentage	5.8%	5.8%	7.2%	4.3%	1.4%	8.7%	1.4%	2.9%	1.4%	1.4%	1.4%		



Post-Test
Number of Students
25
20
15
10
5
0
10
15
20
25
30
More
Score

Post-Test



Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Score	8	9	10	12	13	14	15	16	17	18	19	20	21
Percentage	4.3%	6.4%	8.5%	4.3%	4.3%	4.3%	4.3%	6.4%	6.4%	10.6%	14.9%	8.5%	6.4%
Number	14	15	16	17	18	19	20	21	22				
Score	22	23	24	25	26	27	28	29	30				
Percentage	10.6%	8.5%	6.4%	6.4%	2.1%	4.3%	14.90%	2.10%	4.30%				

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