THE EFFECT OF A FLIPPED CLASSROOM ON STUDENT ACADEMIC ACHIEVEMENT AND THE GENDER GAP IN HIGH SCHOOL PHYSICS

by

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(Under the Direction of Julie Kittleson)

ABSTRACT

The flipped classroom has become a popular teaching method with many high school teachers. Teachers provide students with learning opportunities outside of the classroom to gain content knowledge and then use class time to reinforce, through collaborative and or active learning activities, the content. The flipped class has been gaining popularity though little statistical research has been done to evaluate the effectiveness of this teaching method. The purpose of this study is to examine how well students learn physics content by using the flipped classroom, if the gender gap is reduced in a flipped classroom, and to identify students' perceptions of their learning in a flipped class environment.

The research was conducted in two Honors Physics classes at a high school in rural Georgia. Students were taught four units of physics; two units using a traditional teaching method and two units using the flipped classroom method. A quasi-experimental design was used because random groups could not be assigned. Both groups acted as the experimental group and the control group at different times in the study.

In this study, it was found that there was no statistically significant difference between the two methods of teaching on unit tests and there was not a significant difference in gains between genders for the different methods. Student survey showed that students preferred traditional teaching methods over the flipped class environment.

INDEX WORDS: Flipped Classroom, Conceptual Knowledge, High School Physics, Gender

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DEDICATION

This academic writing is dedicated to my husband, Kip Jones, and my son Jackson. They have provided me with encouragement and support over the years. It is also dedicated to my parents who have supported me in my passions and my many years of learning.

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INTRODUCTION

In today's society, there is an increased prevalence of technology; smart phones, laptops, wireless Internet in almost every coffee shop and restaurant. People are connected to each other and the world in a way unseen 20 years ago. Technology has the potential to change education. "The challenge for our education system is to leverage technology to create relevant learning experiences that mirror students' daily lives and the reality of their futures…We must bring 21st century technology into learning in meaningful ways to engage, motivate, and inspire learners of all ages to achieve" (Transforming American Education: Learning Powered by Technology, 2010, pg. vi).

As technology develops, student culture also changes making it necessary to develop improved methods of teaching that complement and enhance the learning styles of students. Integrating technology in the classroom can be beneficial to students; results show that students perceive technology to be effective in their learning, preparing them for their future, and increasing their motivation and confidence in class (Mishra & Koehler, 2006). Technology can be used to transform the physics classroom by creating a learning environment that not only teaches physics concepts, but teaches students the skills needed to think like a scientist and to become better problem-solvers.

According to the U.S. Bureau of Labor Statistics' Occupational Outlook Handbook, by the year 2018, 16 of the 30 fastest growing occupations in the United

States will be in Science, Technology, Engineering, and Mathematics (STEM) jobs, creating a need to educate people so that they are able to fill these positions.

> Computer and mathematical science occupations are projected to add almost 785,700 new jobs from 2008 to 2018. As a group, these occupations are expected to grow more than twice as fast as the average for all occupations in the economy. (Monthly Labor Review, 2009, p. 85)

Because of the increase in STEM related jobs, it is imperative that the high school curriculum continues to evolve to prepare students for these opportunities. An emphasis on advanced mathematics and science is a goal of current education reform efforts, with a trend to require a physics course for all students in high school before graduation. The American Diploma Project (ADP) Network encourages states and school districts to adopt graduation benchmarks that students must complete the science courses biology, chemistry, and physics for graduation. Currently, 20 states and the District of Columbia have adopted these graduation requirements. The percentage of high school students who earned physics credits increased from 24% to 39% from 2005 to 2009 (Science and Engineering Indicators, 2012).

In November of 2009, President Obama presented his Educate to Innovate campaign to “improve the participation and performance of U.S. students in science, technology, engineering and mathematics (STEM)” which includes expanding “STEM education and career opportunities for underrepresented groups, including girls and women” (Transforming American Education: Learning Powered by Technology, 2010, p. 3). Increasing the number of girls who take physics may be a way to help fill available STEM positions. Today, women are not competing equally in the area of physics. Only

21% of students in undergraduate physics programs are women, and the number drops to 14% for PhD's. In the high school classroom, only 31% of physics teachers are women, limiting the number of positive role models for young females (McCullough, 2007). In 2009, 99,755 students took the AP physics Tests (AP physics B, AP physics C: Electricity and Magnetism, and AP physics C: Mechanics, where AP physics C is calculus based). Only 32.3% of the students were females; with 34.9 % of AP physics B and 25.8% of the AP physics C students being female (AP Central Summary Reports: 2009, 2010).

The purpose of this study is to examine how well students learn physics content by using the flipped classroom, if the gender gap is reduced in a flipped classroom, and to identify students' perceptions of their learning in a flipped class environment. A flipped classroom is one in which students are required to perform activities outside of class that are traditionally performed during class, such as pretests, quizzes, and note-taking (Bergmann & Sams, 2012). Doing these tasks outside of class allows students to spend valuable class time engaged in active learning. One purpose of a flipped classroom is to make class time a time during which students can engage in active learning. Active learning is derived from the basic assumptions that learning is by nature an active venture and that different people learn in different ways (Meyers & Jones, 1993). It is not a set model of teaching; rather it encompasses a variety of teaching methods that allow students to go beyond passively listening to a teacher lecture. "Active learning involves providing opportunities for students to meaningfully talk and listen, write, read, and reflect on the content, ideas, issues, and concerns of an academic subject" (Meyers & Jones, 1993, p. 6). The role of the teacher must be redefined as one that helps students to learn, rather than as a disseminator of information. Technology is key to a flipped classroom, and in this study technology refers to computer equipment, software, hardware, and programs that are used by the teacher and/or student to enhance the traditional classroom experience.

Research Questions

The research questions framing this study are:

1. How does the implementation of the flipped classroom model increase student conceptual knowledge in physics?

2. What is the difference in conceptual gain between girls and boys when implementing the flipped classroom model?

3. How do student perceptions of their learning experiences vary between a flipped classroom and a regular classroom?

Classroom instruction is the independent variable with two levels, traditional and flipped. Student conceptual growth is a dependent variable, which, in theory, will show greater gains by students when participating in the more effective of the two classroom models. It is hypothesized that students in a physics class will benefit from the flipped class method due to the transitioning of class time from passive learning activities, such as lecture, to active learning activities and increased collaborative group work. It is also hypothesized that any "gender gap" will be reduced for the flipped class model. It is believed that students who participated in the flipped class and have a larger gain in conceptual knowledge will perceive their learning experience as a more positive experience than the traditional class model.

CHAPTER 2

LITERATURE REVIEW

Students, even those who do well in the math portion of physics, often do not understand the underlying concepts behind physics phenomena. Research has shown that active learning increases students' conceptual knowledge in physics and a flipped class model is a type of active learning that allows teachers to utilize their available technology to enhance their class (Cunningham & Duffy, 1996; Mazur, 2007; Meyers & Jones, 1993). This study investigated the efficacy of the flipped classroom model in high school physics by evaluating the increase in conceptual knowledge of the students. This literature review looks at conceptual knowledge in physics, active learning, flipped classrooms, different types of technology used in the physics class, and how these affect learning difference between the girls and boys.

Conceptual Knowledge in Physics

Physics has been traditionally taught as a math-based science that is so heavy in the math that the concepts are often overlooked or teachers misinterpret correct mathematical computation as conceptual understanding. Streveler, Litzinger, Miller, and Steif (2008) identified major weaknesses in students' understandings of mechanics. They found that students have a fundamental lack of understanding of the basic quantities, interchanging velocity and acceleration, and viewing force as non-existent in static situations, and students do not understand the relationships between these quantities, recognizing acceleration as the result of multiple force interactions. Students become experts at rearranging equations to solve problems without truly understanding the physics behind the problems. Solving numerical problems, though, does little to facilitate a conceptual change and the ability to find a numerical solution does not show a true understanding of physics (McDermott, 1993).

Understanding concepts is more than knowing just facts. Conceptual knowledge is the acquiring of concepts and the ability to cohesively relate the learned concepts to a more elaborate function (Perkins, 2006). It deals with the ability of the learner to connect between webs of concepts. This is important because the student's recall of a concept will initiate the recall of the interconnected web of facts (Zirbel, 2006). Understanding facts beyond rote memorization is essential to a person's growth in conceptual understanding. It is not sufficient for students to simply define force, rather they must understand how force causes acceleration, the interaction of forces and the importance of these interactions in their lives (Streveler, 2008). Halloun and Hestenes (1985) showed that even though most students can recite Newton's First Law of motion before they reach high school, they carry with them a common misconception for that an inertial or impetus forces is needed for an object to maintain its motion, a violation of the First Law.

In physics, students are expected to learn the concepts of physics as well as apply mathematics to connect the concepts. Rittle-Johnson (2006) discusses the difficulty many students face in their ability to transfer knowledge to new problems or situations. For students to be successful in physics they must be able to engage in procedural learning and transfer in order to use their current knowledge and apply it to new problems. Procedural learning is the ability to execute action sequences to solve familiar problems, procedural transfer is the ability to extend known procedures to novel contexts, and conceptual knowledge is understanding principles governing a domain and the interrelations between units of knowledge in a domain (Rittle-Johnson, 2006, p. 2). Though researchers disagree on the emergence of conceptual knowledge relative to procedural knowledge, it has been shown that a gain in one type of knowledge leads to gains in the other type of knowledge. Thus working to improve a student's conceptual knowledge will also increase their procedural knowledge, leading to a more complete understanding of physics (Rittle-Johnson, 2006).

More research in conceptual knowledge and physics is in the realm of student misconceptions. Reiner et al. (2000) proposed that students create analogies to physical substances in order to understand concepts that cannot be directly observed. Chi (1994) defines emergent processes as those in which "observed phenomena are not directly caused by the underlying physical processes, but rather 'emerge' indirectly from them" (as cited in, Streveler et al., 2008, p.281). Students will then associate the emergent process with the direct cause of the phenomena. In creating analogies and associations between emerging processes, along with misinterpretation of observed phenomena, students may develop a set of misconceptions. A misconception, as defined by Zirbel (2007), is "a concept that is not in agreement with our current understanding of natural science" (p. 5). A common misconception deals with Newton's Third Law of Motion. Because students observe a bug being squished on their windshields, they interpret this as the car exerting more force on the bug than the bug exerts on the car. Though students can recite "for every action there is an equal and opposite reaction” they do not associate this with an interaction between a bug and a car.

Students create a set of beliefs from their previous experiences and direct observations, which they bring into the physics class. Roger A. Freedman, physics professor at University of California, Santa Barbara, points out that “students arrive in their first physics course with a set of physical theories that they have tested and refined over years of repeated experimentation” and “based on their observations, students have pieced together a set of ‘common sense’ ideas about how the physical universe works” (1996, p. 314). This would be beneficial to the teacher if the students entered class with the correct ideas, but as Freedman explains, “these ‘common sense’ ideas are in the main incompatible with correct physics. Worse still, these erroneous ideas are robust and difficult to dislodge from students' minds, in large measure because these ideas are not addressed by conventional physics instruction” (1996, p. 314).

Even deep into the semester, many students will understand what they are supposed to learn, without altering their own beliefs. Eric Mazur found this to be true when he administered a test on collisions to his introductory physics class and a student asked “‘Professor Mazur, how should I answer these questions? According to what you taught us or by the way I think about these things?’” (Mazur, 2007, p 3). So, the teacher not only must identify these misconceptions prior to teaching, but must teach the correct concepts in a manner that will cause the student to “unlearn” their preconceived ideas. This was shown by Mazur and Freedman in the discrepancy between the results of their qualitative and quantitative tests. Students construct understanding from experience and they build upon the foundation of their current understanding. In order for students to learn effectively, they must take responsibility for their own learning, which they cannot do in a passive learning environment (Cunningham & Duffy, 1996; Mazur, 2007; Meyers & Jones, 1993).

Physics has been taught as an exploratory class and problem-solving subject, skills that are best developed by practice; more problem-solving makes for better problem-solving skills. Science labs are an integral part of learning, especially in the physical sciences. In this social context, it is imperative that physics be taught with an emphasis on topics that are relevant to the lives of both male and female students, such as sports, medicine, home, and transportation. This allows students to connect with the subject and take ownership of their learning (Murphy & Whitelegg, 2006, Reid, 2003).

Active Learning

Active learning has become increasingly popular in the college physics courses and in high school physics classes, though most of the research is from college courses. Science is a not just learning about facts, but rather a way of understanding the world. E. Peter Volpe (1984) stated:

> Public understanding of science is appalling. The major contributor to society's stunning ignorance of science has been our educational system. The inability of students to appreciate the scope, meaning, and limitations of science reflects our conventional lecture-oriented curriculum with its emphasis on passive learning (as cited in Michael, 2006, p. 159).

It seems as though there is a major revolution in the physics academia world. Freedman, Mazur, Meg Urry, the Israel Munson Professor of physics and Astronomy at Yale University, John Belcher and Peter Dourmashkin, both professors of physics at

MIT, are all leading the way to a change in teaching methods for introductory physics. Freedman and the others recognize that students gain very little knowledge from traditional lecture and, even though they may perform well on tests, leave the class with minimal understanding and/or appreciation for the physical phenomena of our universe. An emphasis on teaching the fundamental concepts infused with the math is becoming more prominent in physics education. Teachers must transform their classroom from the traditional teacher-center lecture model, where students passively take notes and memorize facts, into a class where students take an active role in their learning (Michael, 2006).

Roger Freedman asks the question “How, then, should the nature of physics instruction be changed?” (1996, p. 317). Freedman outlines the process and the benefits of active learning. Students are engaged by participating in a constructive activity during lecture, this allows them to be involved in the lecture, rather than being a passive note-taker. Next, students are asked to discuss the topic with their peers and provide rationalization for the ideas. In doing this, students must use higher order thinking skills rather than just rote memorization. Students then get immediate feedback on their level of comprehension of the topic. This also benefits the teacher as they can identify the how the students are progressing. Teachers should take this opportunity to correct any misconceptions and clarify areas of confusion.

Integrating technology in the physics classroom can create a more effective learning environment. Wieman and Perkins (2005) define effective physics instruction as “instruction that changes the way students think about physics and physics-problem solving and causes them to think more like experts – practicing physicists” (p. 36).

Traditional lectures present too much information to the student without actively engaging them in their learning. In doing this, the student becomes more disconnected from the realm of physics and sees physics phenomena as facts learned through rote memorization not internalization (Weiman & Perkins, 2005).

Physics education is moving away from the traditional teacher-centered class to a more actively engaged student-focused environment. One of the important aspects of this class structure is peer interaction. Mazur argues that his process “forces students to think though the arguments being developed, and. . . provides them (as well as the teacher) with a way to assess their understanding of the concept” (as cited in Beatty et al., 2006, p. 72) and he suggests that their collective knowledge spreads among the students.

Critiquing peers is another active learning strategy that may enhance conceptual growth in students (Odom, Glenn, Sanner, & Cannella, 2009). Critical discussions between students allow for, and encourage, fostering of new ideas. Students gain deeper understanding of conceptual ideas when they are allowed to critique models, established scientific theories, their own ideas and their peers’ ideas. An actively engaged classroom allows more opportunities for student critiques by using generated computerized objects, using generic and/or directed prompts to encourage individual or peer critique, and designing activities that lend to critique, for example comparing and contrasting (Shen, 2010). Classroom management systems, online simulations and classroom response systems are three types of technology that can elicit one or more opportunities for student critique.

Active classrooms may vary in their implementation, but they should all share specific traits to maximize learning. An active classroom is one where students spend much of the class time actively thinking, talking or doing physics rather than passively listening to the teacher. Peer interaction is essential in an active class because communication between students allows for the discussion, sharing and evaluating of ideas that allows for individual construction of knowledge. Students must receive immediate feedback to ensure that misconceptions are confronted and altered, and that new misconceptions are not formed. The teacher is responsible for engaging the students to facilitate learning, while the students are responsible for their actual learning (Knight, 2002).

In researching different technologies, the unifying theme was that the implementation of an active learning physics class was beneficial to the conceptual learning of the students. With the use of technology, concepts can be delivered to students in a new way. No longer do students have to try and visualize concepts from descriptions and pictures in a textbook, they can now use simulations found on the Internet in educational games and on different scientific websites. This allows the student to have a better connection with the material they are studying.

Flipped Classroom

The flipped class model is a relatively new idea in the teaching community that has been increasing in popularity in education and in the press. This revolutionary idea has become popular due to the publicity of the Kahn Academy, "a not-for-profit [organization] with the goal of changing education for the better by providing a free world-class education to anyone anywhere" (http://www.khanacademy.org/about, 2012).

In the flipped class model, students receive initial content instruction at home through various media devices and work with the teacher and through peer collaboration in class to enhance their knowledge. “The idea of the flipped class started with lecture and direct instruction being done at home via video and/or audio, and what was once considered homework is done in class. So, the order of the ‘lecture’ and ‘homework’ components of the class are, well – flipped” (Bennett, Kern, Gudenrath & McIntosh, 2011, para. 1).

The history of the flipped class model is not clearly documented since there is not one term that definitively defines or describes the flipped class model. In 1990, Eric Mazur of Harvard wanted to change his traditional teaching methods when he noticed that his students did not understand basic concepts in his physics class. Mazur developed what he calls Peer Instruction as a way to actively engage his students during class. Students were expected to familiarize themselves with the concepts through reading the text prior to class. Once in class, Mazur inserts carefully designed questions to elicit meaningful discussion among students (Mazur, 1996). Though, initially, Mazur’s students were expected to use the textbook to prepare themselves for class, with the technological advances, more resources are available to students outside of class and the textbook. Mazur stated, “I believe that we are just seeing the beginning of the process and the computer will soon become an integral part of education. Computers will not replace teachers, but they will certainly provide them with an important dynamic tool for improving the quality of education” (Mazur, 1991, p. 38).

Lage, Platt, and Treglia (2000) began using a flip class model they called the Inverted Classroom; “inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa" (p. 32). Students were expected to come to class prepared to discuss the relevant material, by viewing presentations or videotaped lectures. At the beginning of each class, students were given an opportunity to ask questions about the material, which often led to mini-lectures on the topic; next the students participated in an economic experiment to enhance understanding of the material. After the experiment, the remaining time in class was used to complete worksheets and review questions. Review questions were answered in peer groups with whole class presentation of their results. A Likert-scale and open-ended questions were used to measure student perception. Results indicated that students preferred the inverted class design, especially women; "Both instructors noted that women students were more active participants in the inverted class than in traditional classes, suggesting they were more comfortable in the cooperative classroom environment" (p. 41).

At the University of Wisconsin, Foertsch, Moses, Strikwerda, and Litzkow (2002) used an online streaming video and multi-media application, eTEACH, to transform a large, lecture-based computer science course for engineering majors into a student-centered, problem solving class environment. Students watched lectures online outside of class allowing more class time for small group activities and working on practice problems with the guidance of professors and teaching assistants. Their results showed that the majority of the students felt that the reverse design of the class "significantly enhanced the usefulness, convenience, and value of the course. About two-thirds of the students thought that viewing lectures online at their own convenience enhanced their ability to understand and review lecture material, and as a result had a positive impact on their learning” (p. 273).

Bergmann and Sams (2012) are often credited with being the first to implement the flipped class model in secondary education. The two high school chemistry teachers were looking for ways to record lectures for students who missed class. Because of their rural location, students often missed class for sports and other extracurricular activities. “We were spending inordinate amounts of time reteaching lessons to students who missed class, and the recorded lectures became our first line of defense” (p. 17). They found that other students were watching the lectures for review and teachers from other schools were using their lectures as extra study aides for students. Sams noted, “the time the students really need me physically present is when they get stuck and need my individual help. They don’t need me there in the room to yak at them and give them content; they can receive content on their own” (p. 17). The two decided to record all their lectures, place them online and spend class time actively engaging their students.

Though the flipped class model can be implemented in different ways, the most common is for the teacher to use video lectures posted online for students to watch from home. The advantage of the flipped classroom model is that it facilitates self-paced learning, flexible scheduling and online learning among other things (Bennett, 2011). Because the students are watching the lectures at home, they can take as much, or as little, time as they need to obtain the information. This is extremely valuable for the student who writes slowly, needs information repeated, or has a hard time following the teacher while taking notes. Another advantage of the flipped class model is that by eliminating or reducing in-class lecture, students spend valuable class time engaged in active learning:

> One of the greatest benefits of flipping is that overall interaction increases: Teacher to student and student to student. Since the role of the teacher has changed from presenter of content to learning coach, we spend our time talking to kids. We are answering questions, working with small groups, and guiding the learning of each student individually. (Bergmann & Sams, 2012, p. 27)

Because this is a relatively new model, there are few research studies on the flipped classroom, though many teachers around the country have begun to implement this model and find it very rewarding. Greg Green principal of Clintondale High, an urban Detroit area school, implemented the flipped class model in the 9th grade core classes. In all four areas, Math, Science, English and Social Studies, test scores improved dramatically, while discipline problems decreased. “In English, the failure rate went from 52% to 19%; in math, 44% to 13%; in science, 41% to 19%; and in social studies, 28% to 9%” (Green, 2012, para. 1) and administrators had to deal with only 249 discipline cases as compared to 736 cases from the prior year (Roscorla, 2011). Because students are more actively engaged in class, they increase their learning experience and spend less time getting into trouble.

Technology in the Classroom

Technology is essential for the flipped class model to be successful in the class. Technology allows the teacher to provide the students with learning opportunities beyond the classroom. A flipped class model requires students to gather preliminary information outside the class and, though some information can be obtained by reading the textbook, virtual lectures and activities can be more engaging for many students. Also, teachers can monitor the progress of the students as they participate in online activities. Technology provides the immediate feedback that is beneficial for both student and teacher to assess understanding and correct misconceptions. Students can perform hands-on labs in the classroom and evaluate their data and compare with data from virtual labs completed at home (Finkelstein et al., 2005). Specific technologies used in a flipped class model could include: course management systems, online simulations, and classroom response systems. Course management systems allow the teacher to store and organize lectures and related activities for student access from home. Online simulations provide students with virtual lab experience that helps to connect information to real world examples. Classroom response systems are an effective tool for teachers to monitor participation and understanding of the students. These different technologies allow the teacher to transform the traditional lecture classroom into an effective flipped classroom.

Course management systems (CMS) or learning management systems (LMS), such as CourseCompass, BlackBoard, and MOODLE, have been used in higher education for many years. Course management systems are, at the least, an organizational tool for teachers to deliver materials to their students. CMS are another tool that allows the physics teacher to create an actively engaged classroom for students. Through the CMS, teachers can provide interactive tutorials, administer interactive quizzes, collect problems and homework digitally, provide students with lecture notes, integrate simulations into activities and tutorials, foster communication between students with forums and can receive feedback from students (Seidel et al., 2008; Teresa & Serrano-Fernandez, 2009).

When used effectively, CMS can enhance students' cognitive development, help students construct their conceptual knowledge, and promote positive peer interactions and critiquing. With CMS, teachers can create quizzes and tutorials or homework problems that provide students with prompts or hints, if needed, provide instant feedback and allow for multiple attempts. The immediate feedback allows students to correct their mistakes and prevents students from wondering if they were correct and lending to the development of misconceptions. Hints and prompts lead the students to the correct answer, and, more importantly, it leads them to the correct or more efficient problem-solving technique. This helps to bridge the gap between novice and expert problem-solvers (Krusberg, 2007).

The benefits of CMS include teacher-student interaction in real time, which provides students the ability to share knowledge, expose misconceptions and gaps in knowledge for the teacher to address and for peer interaction. Course management systems allow students and teachers to utilize the components needed to successfully implement a flipped class, including online quizzes, video lectures and online laboratory simulations.

By implementing the flipped class model, students can view the lectures at their own pace and engage in meaningful discussions in class, rather than passively listening to their teacher. Using effective technology allows students to receive immediate feedback and they can be more responsible for their learning. Traditionally, female students have not performed as well in physics as their male counterparts. Encouraging girls to take an active role in their learning allows girls to take ownership to their gained scientific knowledge.

Gender

Females are not competing equally in the area of physics. Only 21% of students in undergraduate physics programs are women, and the number drops to 14% for PhD’s. And in the high school classroom, only 31% of physics teachers are women, limiting the number of positive role models for young girls (McCullough, 2007). In 2009, 99,755 students took the AP physics tests (AP physics B, AP physics C: Electricity and Magnetism, and AP physics C: Mechanics, where AP physics C is calculus based). Only 32.3% of the students were girls; with 34.9 % of AP physics B and 25.8% of the AP physics C students being female. In 2016, the number of female test takers rose to 36% (AP Central Summary Reports, 2009, 2016).

The literature on gender in science education suggests that, to transform girls’ participation and learning in the physics classroom, we must think about ways to engage girls in different kinds of educational activities that promote deeper meanings of physics concepts. Carlone discusses the evolution of the attempt to close the gender gap in science. The first solution to closing the gap was to attempt to explain the lower achievement of females in science to cognitive or social differences between males and females. Later research called for more gender equity in the science classroom; teachers needed to pay more attention to their interaction with female students. A rise in the area of feminist science was the next major movement. This called for creating a science curriculum with a feminist perspective; one where learning grows out of context rather than from content. “In other words, calls for addressing the gender gap have shifted from attempting to fix ‘‘problems’’ with the girls to attempting to fix the problems with school science ” (Carlone, 2004, p. 393).

So, how are we to fix the problems with high school physics? There are many different suggestions on how to transform the classroom to encourage participation and increase achievement for female students. The flipped classroom allows the teacher to have increased class time to implement several of the suggestions that are discussed in the literature. To enhance the learning experience for females, the Institute of Physics recommends that physics is taught in a way that engages with the interests of young people, that teachers manage their class to ensure active participation by student and that they focus on ideas rather than unconnected facts, and that students feel supported in their education (Institute of Physics, 2006). A flipped class allows for more collaboration, teacher support and active learning in the class.

A traditional example of collaboration and active learning is the science lab. Physics has been taught as an exploratory class and problem-solving subject, skills that are best developed by practice; more problem-solving makes for better problem-solving skills. Science labs are an integral part of learning, especially in the physical sciences. This is especially true for girls; “although laboratory experiences do not improve the physical-science achievement of boys, they do improve the achievement of girls, thereby helping to close the gender gap in these areas” (Halpern, Benbow, Geary, Gur, Hyde, & Gernsbacher, 2007, p33). When grouped with boys, though, girls tend to take a more passive role in lab or hands-on activities, “girls were often relegated to marketing and promoting their groups' creations, while boys performed the ‘get-your-hands dirty’ activities” (Cavanagh, 2007, p. 26). Grouping students into same gender groups or classes as been one recommendation to increasing girls achievement in physics (Carnduff, 2007; Cavanngh, 2007, Murphy & Whitelegg, 2006; Reid, 2003), but gender separated classes are not always a possibility, especially in public high schools. Flipping the physics class provides more time for students to perform science labs and allow students to work in collaborative groups.

A notable change in the curriculum is more emphasis on concepts and the social context of physics is being stressed. In this social context, it is imperative that physics be taught with an emphasis on topics that are relevant to the lives of both male and female students, such as sports, medicine, home, and transportation. This allows students to connect with the subject and take ownership of their learning (Murphy & Whitelegg, 2006; Reid et al., 2003). Physics Education Research (PER) has shown that non-traditional teaching environments, especially those that emphasized cooperative learning and interactive engagement methods, decreases the gap between males and females when looking at gain scores on the Force Concept Inventory (FCI) (Docktor & Heller, 2008; Lorenzo et al., 2006; Pollack et al., 2007). The flipped class is a new teaching model that uses technology to present material to students which allows the teacher to use class time for active learning.

Because technology use is an essential component of the flipped class, it is important to understand how female students view using technology in their education. Reychav and McHaney (2017) found that using technology was beneficial to female students. Their findings suggested that females value social aspects of learning in mobile environments and spend more time in their online application when engaged in collaborative learning. Mistler-Jackson & Songer (2000) discussed how girls think about technology as “embedded in and facilitating human interaction” (p. 461). Because of this, using technology in the class to interact with others may make intuitive sense to girls and encourage them to be active participants in the physics class. The flipped class allows female students to use technology proactively, interpret the information that technology makes available, understand concepts, and become a lifelong learner.

Theoretical Framework

Physics Education Research. Physics has always been a course that is considered tough by most students. Even after finishing a course in physics, most students still feel as though physics is a subject that does not relate to or interest them. Much research has been done in changing this, with the goal of improving physics education, and in the 1990’s, professors in the field of physics began to focus their research around the processes and methodologies of teaching physics. Physics Education Research, or PER, refers to the area of pedagogical research and methods used to study and reform how physics is taught. The goal of PER is to provide instruction that will enhance student learning, increased understanding of concepts, and problem-solving skills, while fostering an enthusiasm for physics. Traditional, teacher-centered lecture has been shown to be ineffective in teaching physics and PER focuses on researching alternative methods to lecture, Peer Instruction, Studio physics, Real Time physics, Workshop physics and modeling (http://perusersguide.org/).

> Physics Education Research has become increasingly popular and has begun to emerge as a credible discipline in its own right, with a growing body of reliable empirical evidence, clarification of research issues, and most important of all, an emerging core of able and committed researchers within physics departments

> across the country…. It is a serious program to apply to our teaching the same scientific standards that we apply to physics research (Hestenes, 1998. p. 465).
>
> Physics education research differs from traditional education research in that the emphasis is not on educational theory or methodology in the general sense, but rather on student understanding of science content. (McDermott, 2001, p. 1127).

Redish (2004) states that there is a need for a specific theoretical framework in PER, one that models student thinking. Students need to construct their ideas and observations into a mental model, or an association pattern that fits information together to represent something. It is easier to understand something new if it relates to an existing fact or understanding. Though the different pedagogies that fall under PER may differ in their applications, they all derive from the epistemological framework of constructivism. Redish also emphasized that students construct their own mental models based on their past experiences so they will have different learning styles. The modern student is used to interacting with technology, so including learning strategies, such as the flipped class, can allow students to embrace their technology to enhance their learning.

Constructivism. The current study is grounded in the ideas of constructivism due to the use of the flipped model where the students are engaged in active learning. Constructivism is the idea that learning should be an active process in which the learner constructs rather than acquires knowledge and that teachers are the facilitators of this construction of knowledge (Redish, 1999). Constructivists view learning as a resolution of conflict between outcomes and expectations of the learner that often becomes apparent through experience, discourse, and reflection. The teacher and peers are sources of resistance that challenge the learners' preconceptions and encourage the building of knowledge (Cunningham & Duffy, 1996). My approach is not that of a traditional constructivist, rather I view this research from the perspective of a pragmatic constructivist, understanding that students learn and retain information if they are involved in active learning, but there is predetermined knowledge that they are working to attain.

A constructivist believes that students have emerging theories about the world and they (students and teachers) should have an active part in learning. Dewey, according to Brooks, urged that education should be viewed as a "process of living and not a preparation for future living" (Brooks, 1993, p 9). Traditional teaching looked at students as though they were blank slates, which the teacher could carve any information onto and it would become a part of the student. We know that this is not true; students come to our classrooms with previous misconceptions or alternative conceptions. These preconceptions can be held so strongly that the student finds it difficult to let go of their ideas in order to create new understandings (Clement, 1993). Misconceptions are developed by students' prior experiences and can be the result of cultural myths, incomplete or out of date scientific information, or vague or oversimplified information (Hartman & Glasgow, 2002).

According to Joan Davis (2001), a constructivist approach in which learners take an active role in reorganizing their knowledge is required when teaching for conceptual change. Using a conceptual change model is very effective in overcoming students' misconceptions. A conceptual change model of teaching involves identifying students' preconceptions and then using various teaching methods to overcome or alter these conceptions. Students must be aware of their misconceptions if they are going to change them; this awareness, with the presentation of different concepts, causes internal conflict, which allows the student to break down their old misconceptions and construct new, more accurate concepts. It is not possible that a teacher can identify all misconceptions in the class, but by using active learning strategies, the teacher can help students to recognize and correct their own misconceptions (Bernhard, 2005; Davis, 2001; Hartman & Glasgow, 2002).

In physics, a conceptual change model of teaching is necessary. Traditional lecture style teaching and many physics texts do not address student misconceptions. Students need effective instruction that helps them to build knowledge of Newtonian concepts through peer interaction. Logical reasoning of Newtonian mechanics is not effective to students who have limited scientific context (Dykstra, Boyle, & Monarch, 1992). In order for a conceptual understanding to occur, a new conception "must be intelligible (students comprehend its meaning), plausible (students believe it to be correct), and fruitful (students find it useful)" (Posner, 1982, p. 8). To increase conceptual knowledge, teachers need to create a constructivist class environment that allows students to challenge their own misconceptions and build meaningful connections these misconceptions and concepts in physics.

Constructivists view learning as a student centered activity; if students are to construct their own knowledge, they should be active participants in the learning process. New learning occurs in the zone of proximal development, "the distance between the actual developmental level as determined by individual problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). To address preconceptions and bring about a conceptual change in the physics class, teachers can implement the flipped class model to create an environment of learning in which the student is an active participant. Allowing the students to take control of the pace in which they learn new material, while still giving them guidance, encourages students to take control of their learning and construct their own knowledge in a more meaningful way; thus creating lifelong learners.

Active learning. Active learning has become increasingly popular in the college physics courses throughout the nation and, though there is little research on the success of this in high school physics, I believe that it is the answer to Freedman's question "How, then, should the nature of physics instruction be changed?" Freedman (1996) discusses the benefits of active learning in his paper:

> First, the students have something constructive to do during the lecture… second, students are forced to discuss physics with their peers and to defend their ideas. Third, students get immediate feedback as to whether or not they understand a concept that has been presented in class, and any points of confusion can be corrected at an early stage in the students' apprehension of the concept. Last, but by no means least, the instructor can learn a great deal about her or his students' understanding of the material. (para. 34)

Active learning can be seen as constructivist learning because it has the many of the same underlying assumptions. Understanding concepts is more than knowing just facts. This was shown by Mazur and Freedman in the discrepancy between the results of their qualitative and quantitative tests. Students construct understanding from experience and they build upon the foundation of their current understanding. In order for students to learn effectively, they must take responsibility for their own learning, which they cannot do in a passive learning environment (Cunningham & Duffy, 1996; Mazur, 2007; Meyers & Jones, 1993).

Active classrooms may vary in their implementation, but they should all share specific traits to maximize learning. An active classroom is one where students spend much of the class time actively thinking, talking or doing physics rather than passively listening to the teacher. They should be engaged in solving problems, sharing ideas, giving feedback, and teaching each other (Johnson, Johnson, & Smith, 1998). Peer interaction is essential in an active class because communication between students allows for the discussion, sharing and evaluating of ideas that allows for individual construction of knowledge. Students must receive immediate feedback to ensure that misconceptions are confronted and altered, and that new misconceptions are not formed. The teacher is responsible for engaging the students to facilitate learning, while the students are responsible for their actual learning (Knight, 2002).

Conclusion

Physics instruction can be improved by providing students with opportunities to learn in a setting that is not traditional. The flipped method allows students to view new material at their own pace allowing for more time in the classroom for active learning activities. Students can learn the material at their own pace by watching the videos at their own pace. If students watch the videos outside of class, this will provide more time in class for active learning in collaborative activities, labs, and projects.

CHAPTER 3

METHODS

Introduction

The purpose of the study was to determine the efficacy of the flipped class versus a traditional class. Does the flipped classroom increase conceptual knowledge in the physics class? Do female students have a greater gain than male students in the flipped class? How do students perceive their learning in the flipped class setting? It is hypothesized that students in a physics class will benefit from the flipped class method due to the transitioning of class time from passive learning activities, such as lecture, to active learning activities and increased collaborative group work. It is also hypothesized that any “gender gap” will be reduced for the flipped class model. It is believed that students who participated in the flipped class and have a larger gain in conceptual knowledge will perceive their learning experience as a more positive experience than the traditional class model.

Context

This study took place at a rural public school in the southeast United States. The high school opened in 2004 and has approximately 1,030 students. This school has been ranked in the top 2 percent of schools nationally (Thompson, 2009) and has been named an Advanced Placement Merit school for four consecutive years. According to the Georgia Department of Education, the student body consists of 87% White, 4%

black, 4% Hispanic, 3% Asian and 2% mixed students and has a graduation rate of 92.5% (GA DOE, 2012).

Participants

For this study, I focused on the students in two high school honors physics classes that I taught. Because of the way classes are scheduled, one class was taught fall semester and the other was taught spring semester. Classes are taught on a 90-minute block schedule for 18 weeks. The fall class consisted of 17 girls and 15 boys. All students signed waivers consenting to research, but one girl left the class before the beginning of the research period and one girl left the class before the research was complete. The spring class consisted of 12 girls and 19 boys. One girl opted not to participate in the research, but all others consented to being part of the research. Students and parent were given a letter with information concerning the study, as well as a consent form.

The classes consisted of junior and seniors, none of whom had taken a physics course prior to my Honors Physics class. Students must complete Honors Chemistry and Honors Math II (Algebra 2) with an 85% or higher in order to take Honors Physics, so all the students were assumed to have similar skill levels.

The units for this study consisted of the mechanics portion of the physics course; kinematics, forces, energy and momentum. Before the research portion of the course, students completed four units of study, nuclear physics, waves, optics and electricity. All of these units were taught using a traditional, lecture style format, so none of the students had been taught using the flipped method before the first unit of the study.

Design

I implemented a switching replications design over four units during the semester. In using a switching replications design, I attempted to control some of the social threats to internal validity. “The implementation of the treatment is repeated or replicated. In the replication of the treatment, the two groups switch roles; the original treatment acts as the control” by their counselors (Trochim & Donnelly, 2008, p. 205). In a switching-replications design, the treatment (e.g., flipped class) was introduced at different times for different groups, which enables an initially untreated group to serve as a control for a treated group. The switching-replications design has been shown to have high internal validity, external validity, and statistical power (Braver & Walton Braver, 1990). Both groups were given a pre-test at the beginning of the course and a post-test at the end.

During the fall semester, students in the physics class were taught using a traditional, lecture centered class model for the kinematics and energy units and the flipped class model was implemented for the Newton’s Law and momentum units. The spring semester students were taught the kinematics and energy units using the flipped class model and a traditional, lecture based class model was used for the Newton’s Law and momentum units. Projectile motion was included at the end of the semester during the momentum unit for both semester courses. The method of teaching was alternated between units, so neither class was taught using the flipped method for consecutive units. This was done to limit the influence of familiarity of the teaching method as a factor in the effect of learning.

The experimental design comparing the flipped and traditional models began after the Electricity unit. The videos for each unit were uploaded to the course management site used by our district, MOODLE, at the start of the unit for the flipped model and were available for access for viewing two days before they are required for class. Each video was no longer than 15 minutes, though some topics required the student to watch more than one video prior to class. The lecture videos were accessible for students in the traditional group the day after the lecture was presented in class. This was to ensure that each student had equal access to study materials prior to the test. The students that were in the flipped model were required to view the videos, while students in the other group were not.

Students in both courses were given guided notes to use during lectures. Guided notes are outlines prepared by the teacher to guide students through a lecture. Guided notes enhance the note-taking experience and to allow students to identify the important points of the lecture in an organized manner (Twyman, 2016). An example of the guided notes is given in Appendix A. Both the online videos and classroom lectures were created using Power Point. The guided notes were identical for each group and both traditional and flipped presentations contained the same information.

The first unit used for comparison was kinematics, or one dimensional motion. Fall semester students (Group One) were instructed through traditional teaching methods, while students in spring semester (Group Two) received the same information using the flipped model. The topics covered in the kinematics unit are (1) scalars and vectors, (2) constant velocity and acceleration, (3) describing motion with pictures (motion maps and graphing), (4) kinematic equations and (5) free fall. For the second unit, forces and Newton's Laws, the topics for this unit included (1) Newton's First Law, (2) Newton's Second Law, (3) free-body diagrams, (4) application of forces (normal, tension, friction, and gravity), and (5) Newton's Third Law. The topics for the energy unit are (1) work and power, (2) kinetic energy, (3) potential energy, and (4) law of conservation of energy. The final unit, momentum, included the topics (1) momentum and newton's third law (2) impulse, (3) law of conservation of momentum, (4) collisions (elastic and non-elastic) and (5) projectile motion. The units and how they were treated are shown in Figure 1.

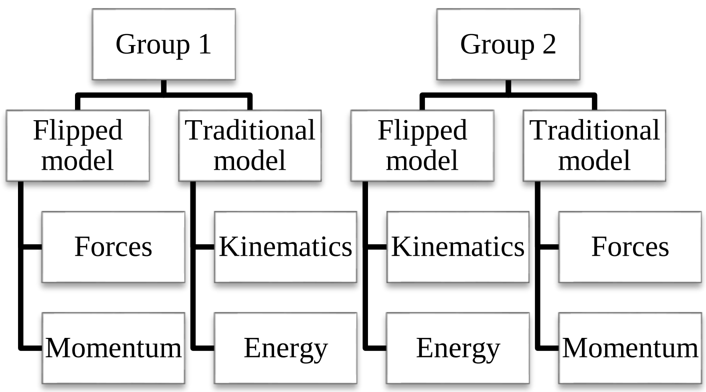

Figure 1.Comparison of Units Taught Under Traditional and Flipped Models.

Each unit taught using the flipped model design consisted of video lectures outside of the class. These videos covered only one or two topics and were 15 minutes or less. Videos were included in a MOODLE lesson. The first page included the video and then a link directed the students to the first question of the quiz. If students answered the question incorrectly, they were directed back to the video. They could opt to go to the next question without answering correctly or they could watch the video again. Once they answered the question correctly, they were sent to the next question. Quizzes consisted of five to ten questions that were related to the video they watched. The day after watching a video, students worked in collaborative groups to work on problems and answer questions related to the lectures they had viewed. The discussion questions ranged from simple vocabulary to more difficult questions that involve problem solving and understanding of the material.

The traditional class covered the same material, but in a more teacher-centered class. Students completed guided notes during lecture. The students did not have the group discussion questions after lecture; these questions were discussed throughout the lecture and students were able to ask questions during lecture if needed. Embedded in the lecture are formative clicker questions; these were the same questions that the flipped model students answered in the online quizzes.

After the lecture, traditional students were assigned both conceptual and mathematical problems for homework. These problems were follow-up and practice questions for students to assess what they understood after lecture. The students in the traditional class were expected to complete the problems at home for homework. Both the traditional and flipped classes were assigned the same problems to work on after lecture. The day after students watched the videos, we would have a question session for students to ask questions over the material they viewed and then the students completed the problems in collaborative groups of two to four students. While working in groups, students would work together on problems and I would walk around and answer questions. Students could take the problems home to finish if needed, but most finished within the class period.

Both groups of students performed the same hands-on labs during class. Labs were done after the first set of problems to ensure that every student had access to the same materials. After the initial problem set and lab, students in the traditional class, there would be a follow up lecture on more difficult concepts or concepts that built on the initial material while the flipped students would watch the lecture on line. Students were assigned one project per unit. The students who were in the flipped class design worked on their projects in class while the traditional students were required to complete their projects at home. The projects for each unit were: Kinematics – write a children's story that included different types of motion, graphs of their motions and motion maps; Newton's Laws – create a video that showed examples of all three laws of motion and create presentation that demonstrated their knowledge of the laws; Energy – design and build a roller coaster out of paper and create a business proposal to sell their roller coaster to an amusement park; and momentum – design and build a Rube Goldberg Machine and create a sales brochure that explained their machine.

Data Sources

Not only am I interested in the effects of flipped teaching on improving the conceptual knowledge of my students, I am interested in the perceptions that my students have of their own learning within a flipped class design. Because this method of teaching is quite different than the traditional class design, students may feel that their learning has been impacted positively or negatively.

A quasi-experimental design was used for this study because of the inability to randomize the groups. Students were administered the Force Concept Inventory (FCI), Appendix E (Hestenes et al, 1992) as a pre-test to assess student understanding of the most basic concepts in Newtonian physics, while also identifying students' misconceptions. The FCI was administered on the first day of the semester before any physics concepts were taught. The FCI is a multiple-choice instrument that has 30 questions, divided into six areas of understanding: kinematics, Newton's First, Second, and Third Laws, the superposition principle, and types of forces (such as gravitation, friction). Each question offers only one correct Newtonian solution, with common-sense distracters (incorrect possible answers) that are based upon students' misconceptions about that topic, gained from interviews. The FCI was developed by Malcolm Wells, David Hestenes and Gregg Swackhamer "to assess student understanding of the most basic concepts in mechanics. The test is universal in the sense that it is limited to concepts that should be addressed in introductory physics at any level from high school through Harvard University" (1992, p. 159).

After each of the four units, a unit assessment was given. Each test consisted of a multiple choice portion and a problem-solving section. The multiple choice questions are conceptual questions; testing the students on the underlying concepts in the unit. Aligned questions from the Mechanics Baseline Test (MBT), Appendix D, were used in the corresponding topics, as well as questions from my tests from previous years. The MBT is a 26 multiple choice instrument that is usually only given as a posttest (Hestenes & Wells, 1992). The MBT covers more topics than I cover in this study, so I did not use it in its entirety as a posttest. For the kinematics unit, I included questions 1, 2, 3, 23, 24, 25; the forces unit consisted of questions 2, 3, 8, 9, 12, 17, 21, 26; the work-energy unit had questions 10, 11; and the momentum units had questions 12, 13, 14, and 22. The problem-solving questions are both mathematical and conceptual in nature. Students must understand how the different equations are connected in order to correctly solve the problems.

At the end of the fourth (final) unit, the students completed a Likert scale survey, Appendix B, which was designed to measure their perceptions of a regular versus flipped classroom setting. The survey was modified from one that was “previously used in a study to examine the efficacy of traditional and blended course delivery methods… designed to determine student perceptions in the areas of content and course delivery, assessment and evaluation, as well as communication and learning experiences” (Johnson & Renner, p. 62, 2012). The survey allowed students to give open-ended responses to several questions to identify specific trends in the students’ perceptions of the efficacy of the flipped class method.

Data Analysis

All quantitative data, with the exception of the survey questions, were analyzed using a two sample t-test to examine if there was a significant difference in performance between the two instructional approaches. I chose to use the t-test for several reasons. In order to use a t-test, certain assumptions must be met. The sample size should be relatively small. The two groups in my study had 30 participants. The study must contain independent data that has two groups and a continuous dependent variable must be present. And the dependent variable has an approximately normal distribution (Independent T-Test, n.d.) I examined the frequency histograms of the values of numeric variables, to detect any possible gross departure from normal distributions and to justify that the theoretical assumption of normal distribution theoretically presumed by the t-test was met. A t-test is considered to be an appropriate method for comparing the means of two groups (Trochim, 2006).

The two groups were administered the FCI as a pretest to determine if they were comparable groups. Research questions one and two were both tested using t-tests to compare the independent variables. A t-test was administered look for statistical differences between the flipped and traditional groups when comparing unit tests and the MBT, and the Hake growth. The same tests were used to compare female and male scores, as well as comparing females in the traditional versus flipped groups.

Twelve of the questions from the Likert survey were treated as ordinal data. The data for these questions are presented in a bar graph with the number of students selecting each response. Even though the data can be presented using parametric tests, in Likert tests

> means are often of limited value unless the data follow a classic normal distribution and a frequency distribution of responses will likely be more helpful. Furthermore, because the numbers derived from Likert scales represent ordinal responses, presentation of a mean to the 100th decimal place is usually not helpful or enlightening to readers. (Sullivan, 2013, p.242)

For the open-ended questions, responses were compiled using an Excel spreadsheet. Each question was analyzed and responses were coded and grouped into five major themes that emerged from similar responses. If a response did not fit into one of the five themes, it was coded as miscellaneous. These responses were reported as percentages.

CHAPTER 4

FINDINGS

The purpose of this study was to investigate how well students learn physics content in a flipped classroom environment in a high school physics class and to determine if there was any difference in learning growth due to gender. Students were taught using a traditional lecture based environment and then in the flipped classroom environment. The traditional class students were taught using power point for lectures and in class quizzes. The treatment group, students in the flipped classroom setting, watched videos outside of class time and took online quizzes to ensure that they watched the videos. In class discussions took place after the students viewed the videos and students worked in small groups on homework assignments.

Student Baseline Knowledge

Students were analyzed at the beginning of the semester to assess their conceptual knowledge in physics using the Force Concept Inventory (FCI). At the end of each unit, students were administered a test that consisted of multiple choice questions, which tested their conceptual knowledge, and word problems, which tested their problem solving skills. The unit tests contained questions from the Mechanics Baseline Test (MBT), Appendix D, and other questions from testing software. At the end of the final unit, students answered questions on a survey to investigate any statistically or practically significant difference in the students' attitude towards the teaching methods they received.

Physics baseline prior knowledge comparison. Students were administered the Force Concept Inventory on the first day of class both fall and spring semesters. Microsoft Excel was used to perform an independent samples t-test comparing the pre-test scores for each class.

Table 1.

Force Concept Inventory Pre-Test in Fall and Spring Semesters

	Semester					
	Fall		Spring			
	M	SD	M	SD	t	*df*
Pre-Test	6.35	2.55	7.70	3.35	1.74	57

The difference in mean scores for the FCI was not statistically significant with a p-value of 0.086.

A t-test was also used to evaluate the difference in prior knowledge between female and male students.

Table 2.

Force Concept Inventory Pre-Test by Gender

	Gender					
	Females		Males			
	M	SD	M	SD	t	*df*
Pre-Test	5.56	1.96	8.12	3.25	3.49***	57

Note. *** = $p \leq .0001$

There was a significant effect for gender for the FCI score, with male students receiving higher scores that female students. This indicates that the male students have more prior knowledge of physics concepts than their female classmates.

Findings Regarding Research Question #1

The first research question asked how the implementation of the flipped classroom model increased student conceptual knowledge in physics. It was hypothesized that students in a physics class will benefit from the flipped class method due to the transitioning of class time from passive learning activities, such as lecture, to active learning activities and increased collaborative group work. During the first unit, Kinematics, and the third unit, Work and Energy, students in the fall semester were taught using traditional teaching methods, while the spring semester students were taught using the flipped method. The second and fourth units, Newton's Laws and Momentum, were taught using the flipped method in the fall and traditional teaching methods in the spring. The multiple choice questions of the test consisted of questions from the Mechanics Baseline Test and the testing software from the textbook. These questions assessed the students' conceptual understanding of the physics concepts taught that unit. Students were taught with two units of flipped instruction and two units of traditional instruction.

Mechanics Baseline Test. The MBT consists of problems that are both conceptual in nature and problem solving. I selected only the questions that were relevant to the topics that were discussed in class and were concept-based questions. There were twenty questions with more questions from the kinematics and forces units. The questions were organized by flipped versus traditional students and a percentage of the correct responses were calculated. The percentage of the scores that were correct were compared using a t-test using Microsoft Excel. Table 3 shows the distribution of the scores for the MBT.

Table 3.

Mechanics Baseline Questions

	Teaching Method					
	Traditional		Flipped			
	M	SD	M	SD	t	*df*
MBT	47.39	22.60	63.21	25.40	1.74	57

The p-value is 0.088, which is large enough to determine that the difference in mean scores for the Mechanics Baseline Test was not statistically significant.

Unit tests. The unit tests consisted of 15 to 20 multiple choice questions that asked conceptual knowledge questions. For each unit, the percentage correct from the multiple choice questions was evaluated with a t-test using Microsoft Excel to identify if there was any statistical difference between the two groups. The t-value is 1.74169 and the p-value is 0.1888, which is large enough to determine that the difference in mean scores for the unit tests was not statistically significant.

Each test was individually analyzed using a t-test to determine if there was any statistical significance between the control (traditional) and the treatment (flipped) groups. The kinematics unit covers linear motion and graphing. The Newton unit covered Newton's Laws, Forces and drawing free body diagrams. There was a statistically significant difference between the two teaching methods, the traditional method and the flipped classroom in the first two units. The Energy unit included the topics of Mechanical Energy, Work and Power. The final unit, Momentum, covered

Momentum, Conservation of Momentum, Impulse and Projectile Motion. There was not a statistically significant difference between the two teaching methods, the traditional method and the flipped classroom for the last two units. The results of the multiple choice questions are summarized in Table 4.

Table 4

Summary of Unit Tests Scores

	Mean (Traditional)	S.D (Traditional)	Mean (Flipped)	S.D. (Flipped)	P-value (α=0.05)
Kinematics	67.24	11.46	78.52	13.57	0.0014
Newton	86.98	7.28	76.01	11.19	0.0001
Energy	73.10	11.94	66.40	19.39	0.12
Momentum	66.69	12.27	68.52	12.95	0.604
Total	73.52	13.79	70.91	14.78	0.19

Summary of research question #1. The first question in this study addressed if there was a difference in the conceptual knowledge in a physics class if the flipped classroom method was used. The first two units showed a statistically significant difference between the traditional and flipped methods. Students performed better in the flipped classroom during the kinematics unit, $t(54) = 3.37$, $p = 0.0014$, but the students in the traditional class outperformed the flipped class during the Newton unit, $t(53) = 4.25$, $p < 0.0001$. The scores for the Energy unit did not differ by teaching method, $t(53) = 1.56$, $p = 0.1241$. The Momentum scores also did not vary by teaching method, $t(51) = 0.53$, $p = 0.6014$. When the unit tests were compared with all questions, there was not statistical difference, nor was there a significant difference in the Mechanics Baseline Test question comparison.

Findings Regarding Research Question #2

The second research question asked if there was a statistical difference in conceptual gain between female and male students when implementing the flipped classroom model. It was hypothesized that any “gender gap” will be reduced for the flipped class model. The FCI pretest showed that there was a statistical difference between males and females in their prior knowledge of physics at the beginning of the semester, as seen in Table 2.

Scores were evaluated in two separate ways for the second research question. A t-test comparing the scores of female students in the flipped classroom to traditionally taught females was performed. The scores of female students to male students in the flipped class was also compared. These tests were performed to evaluate the performance of the female students taught under each method and to assess the “gender gap” after using the flipped teaching method.

Mechanics Baseline Test. There was a statistical difference between teaching methods for females when looking at the MBT scores, $t(26) = -2.83$, $p = 0.0088$. The percentage of the scores that were correct were compared using a t-test and can be seen in table 5.

Table 5.

Mechanics Baseline Questions for Females

	Teaching Method					
	Traditional		Flipped			
	M	SD	M	SD	t	*df*
MBT	45.42	21.80	70.67	25.20	-2.83	26

The percentage of the scores on the MBT that were correct during the flipped class were compared using a t-test. The results indicate that the difference in mean scores between the two groups on the MBT was not statistically significant, $t(26) = 1.06$, $p = 0.30$. Table 6 shows the distribution of the scores for the MBT between males and females.

Table 6.

Mechanics Baseline Questions for Flipped Method by Gender

	Gender					
	Male		Female			
	M	SD	M	SD	t	*df*
MBT	58.83	33.41	70.67	25.20	-1.06	26

Unit tests. There was not a statistical difference between teaching methods when looking at the unit test scores for females. The percentage of the scores that were correct were compared using a t-test. The difference in mean scores between the two methods on the unit test scores was not statistically significant, $t(22) = .65$, $p = 0.52$. Table 7 shows the distribution of the scores for the unit tests.

Table 7.

Unit Tests by Teaching Method

	Method					
	Traditional		Flipped			
	M	SD	M	SD	t	*df*
Unit Test	72.36	13.60	70.37	14.42	-.65	22

The scores on the multiple choice portion of the unit tests that were correct during the flipped class between males and females were compared using a t-test. The difference in mean scores between the two groups on the unit tests was not statistically significant, $t(25) = -0.44$ $p = 0.66$. Table 8 shows the distribution of the scores for the unit tests between males and females.

Table 8.

Unit Tests for Flipped Method by Gender

	Gender					
	Male		Female			
	M	SD	M	SD	t	*df*
Unit Test	71.62	14.83	70.37	14.42	-0.44	25

FCI posttest. The Force Concept Inventory, FCI, was administered to students at the beginning and end of the semester. The FCI was used to evaluate the students' prior knowledge. The post-test was used to test for statistical significance in conceptual gain between males and females. The normalized gain, also known as the Hake gain, is the ratio of the actual gain to the maximum possible gain, which represents the overall gain: $g = \frac{PostTest - \Pr eTest}{30 - \Pr eTest}$, where 30 is the maximum number of correct responses on the FCI. Hake advocates using normalized gain because this measure strongly differentiated between teaching methods, but allows for "a consistent analysis over diverse student populations with widely varying initial knowledge states." (Hake, 1998, p. 66). The Hake gains between the FCI pretest and posttest during the flipped class were compared using a t-test. Table 9 shows the distribution of the scores for the Hake gain on the FCI between males and females.

Table 9.

Force Concept Inventory Growth by Gender

	Gender					
	Male		Female			
	M	SD	M	SD	t	*df*
Hake gain	0.22	0.17	0.20	0.14	0.54	56

Summary of research question #2. Research question two asked if there was a statistical difference in the conceptual gain for females who were taught using the flipped method. There was a significant effect for teaching method, $t(26) = 2.83$, p = 0.0088, with females taught using the flipped method receiving higher scores than females taught in a traditional setting. The comparison of females on unit tests, as well as both the unit test and MBT comparisons between males and females showed no statistically significant differences. The FCI gain scores did not differ by gender, $t(56) = 0.54$, p = 0.59.

Findings Regarding Research Question #3

The third research question asked how student perceptions of their learning vary between flipped and traditional teaching methods. It was hypothesized that students would like the flipped classroom more than the Traditional classroom and that they would feel that they learned more from the flipped teaching method. The results of the Likert survey showed that 83% of the students preferred the traditional method of teaching over the flipped class and only 19% of the students found the flipped classroom to be more engaging than a traditional class setting. Figures 2 and 3 illustrate the distribution of the students' responses.

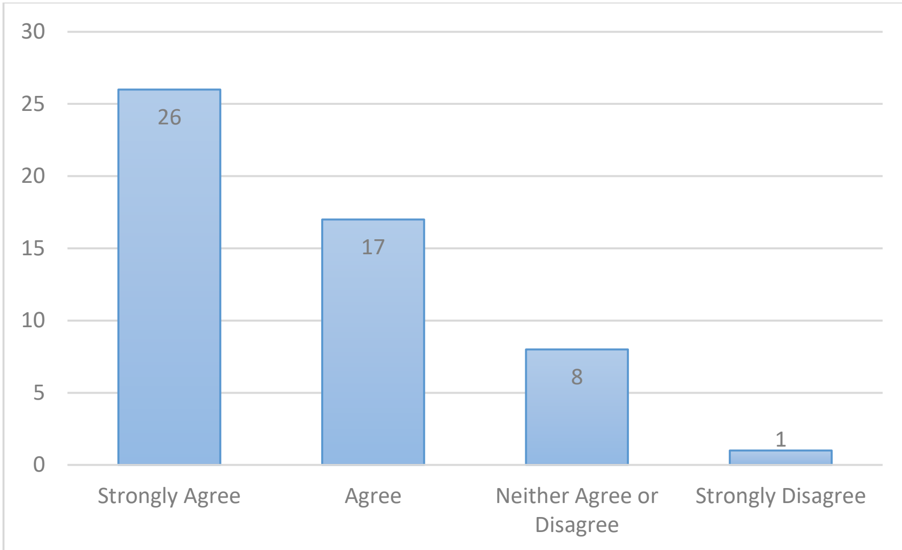

Figure 2: Preference of Teaching Method. I would prefer a traditional teacher led lecture than a video lecture.

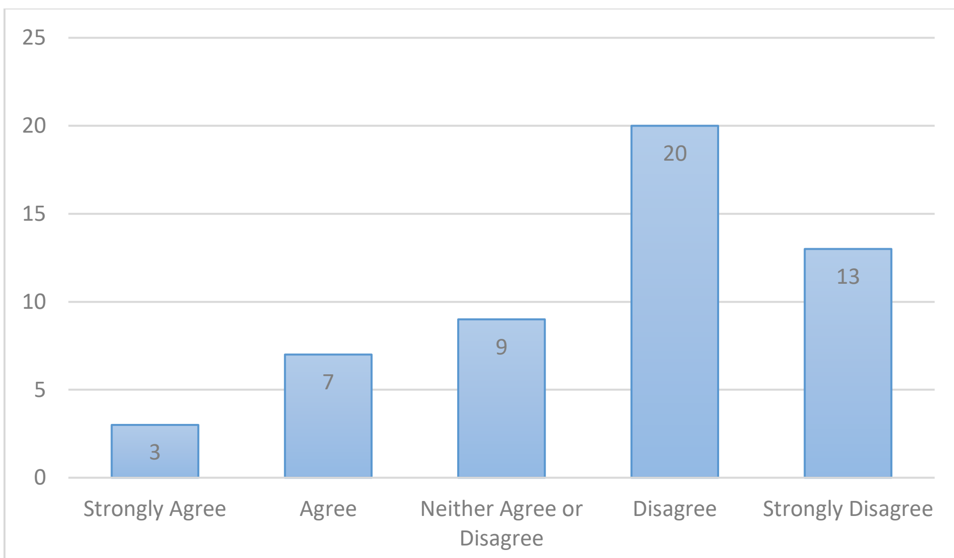

Figure 3: The Flipped Classroom is more engaging than a traditional lecture centered classroom.

Though there was no statistical difference between the tests scores of students between the two teaching methods, 56% of students felt that they did not learn more in the flipped class setting, Figure 4, and 59% said they were less motivated to learn, Figure 5. Only 21% of the students said they would recommend a flipped to a friend, Figure 6.

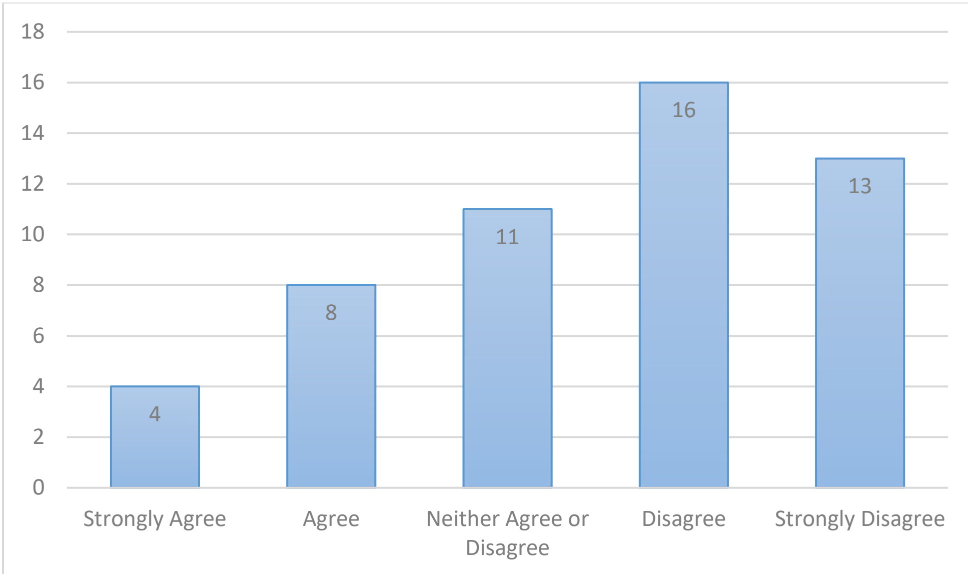

Figure 4: Perceived Learning in Flipped Class. I learned more Physics when taught using the Flipped Classroom.

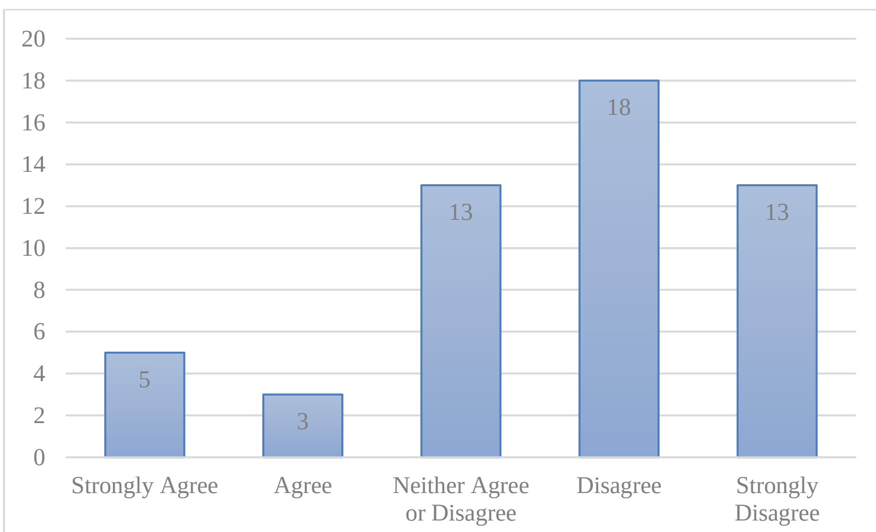

Figure 5: I am more motivated to learn Physics in the Flipped Classroom.

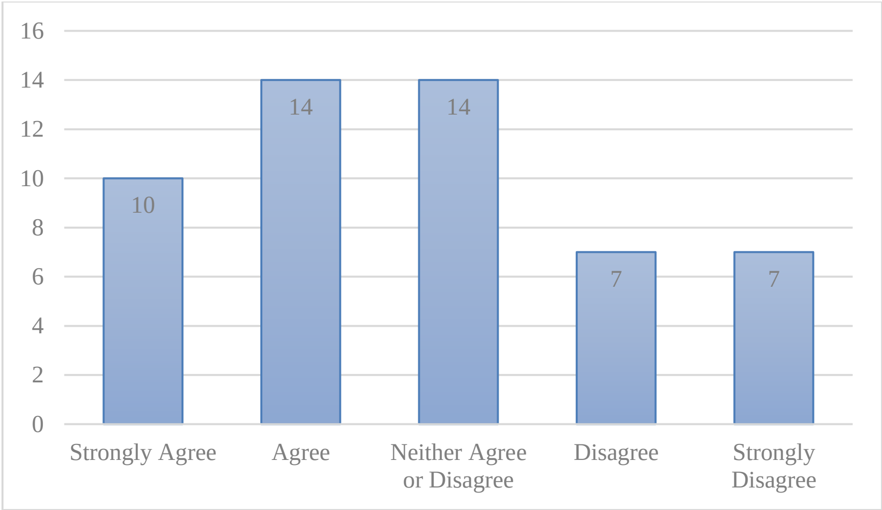

Figure 6: I would not recommend a class that was taught using the Flipped Classroom to a friend.

Students had more confidence in their learning in a traditional environment. Figures 6 and 7 show that 73% of students feel their test grades in the traditional class accurately reflect their learning while only 50% believed that their test grades were reflective of their learning in the flipped class.

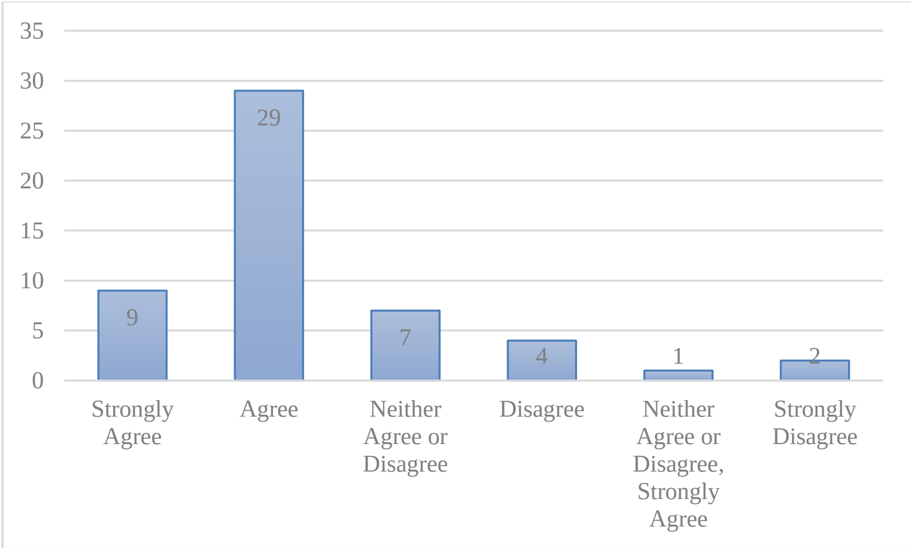

Figure 7: My test grades accurately reflect my learning during the Traditional Classroom units

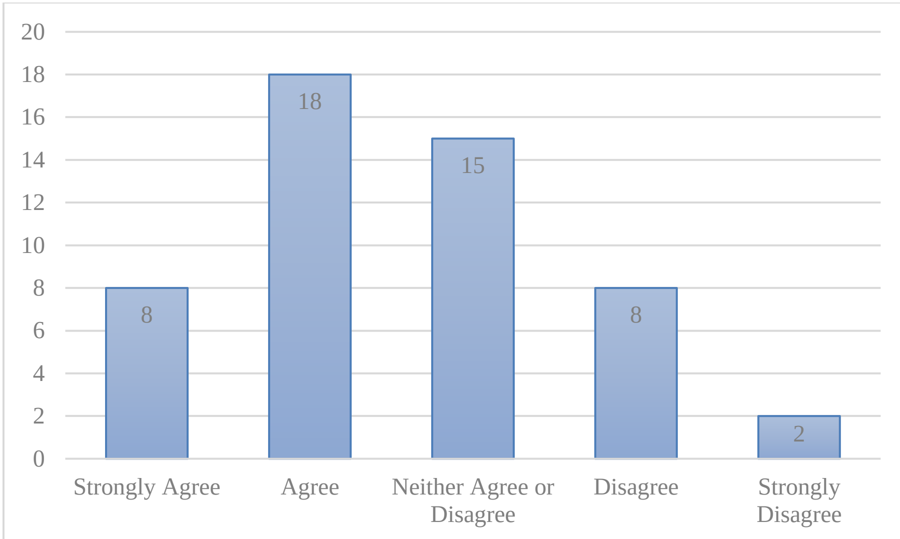

Figure 8: My test grades accurately reflect my learning during the Flipped Classroom units.

One of the main advantages of the flipped class is the availability of the information for students. One disadvantage is that it is necessary for students to take responsibility for watching the videos as many times as needed to understand the material. Figures 9, 10, and 11 show that the majority of the students watched the videos prior to class, 58%, and would rewind when more understanding was needed, 67%. Only 29% of students watched the videos more than once.

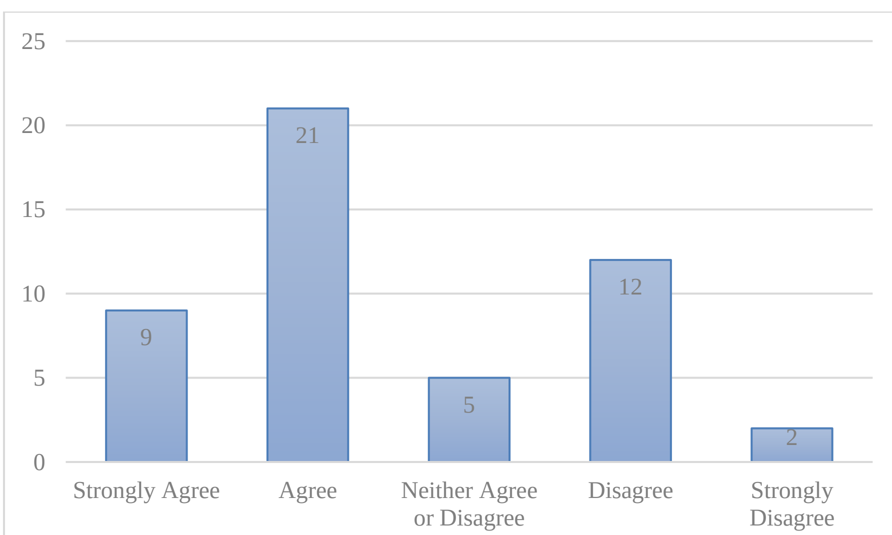

Figure 9: I always watched the video lessons prior to class.

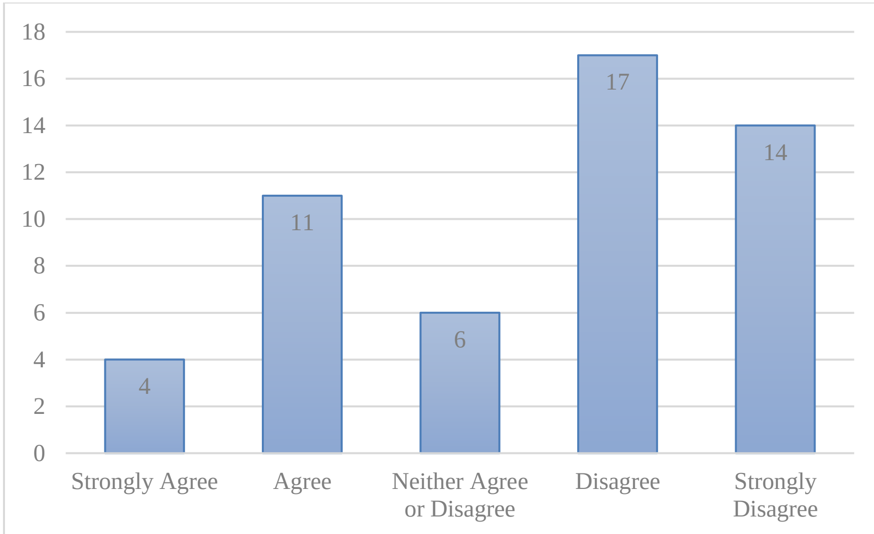

Figure 10: I watched the video lessons more than the once during the unit.

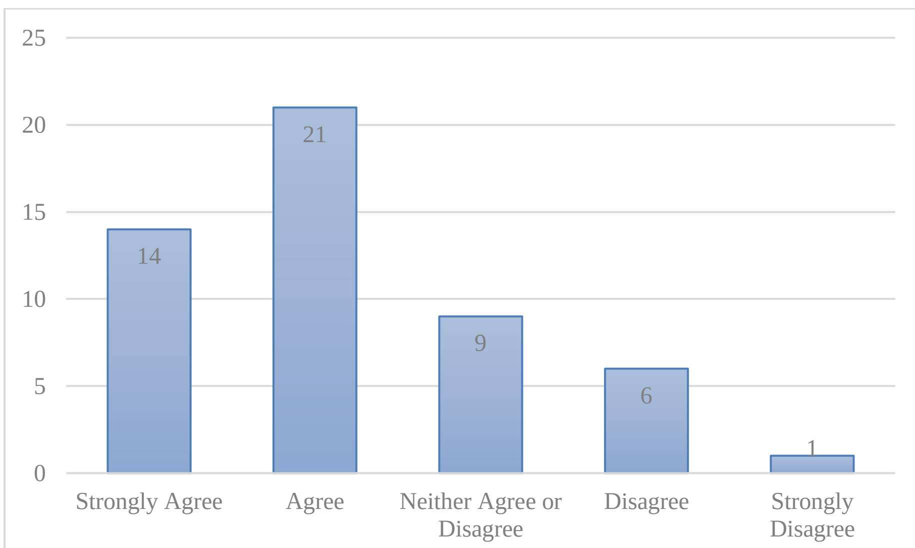

Figure 11: When watching the video lessons, I would stop and rewind when I did not understand a concept.

Students were asked to indicate how certain aspects of the flipped class helped to improve their learning experience during the experimental period. Students could choose more than one answer and some students did not answer this question. Students felt that the availability of the content was the most beneficial aspect of the flipped class, followed by in-class group discussion and group collaboration, Figure 12.

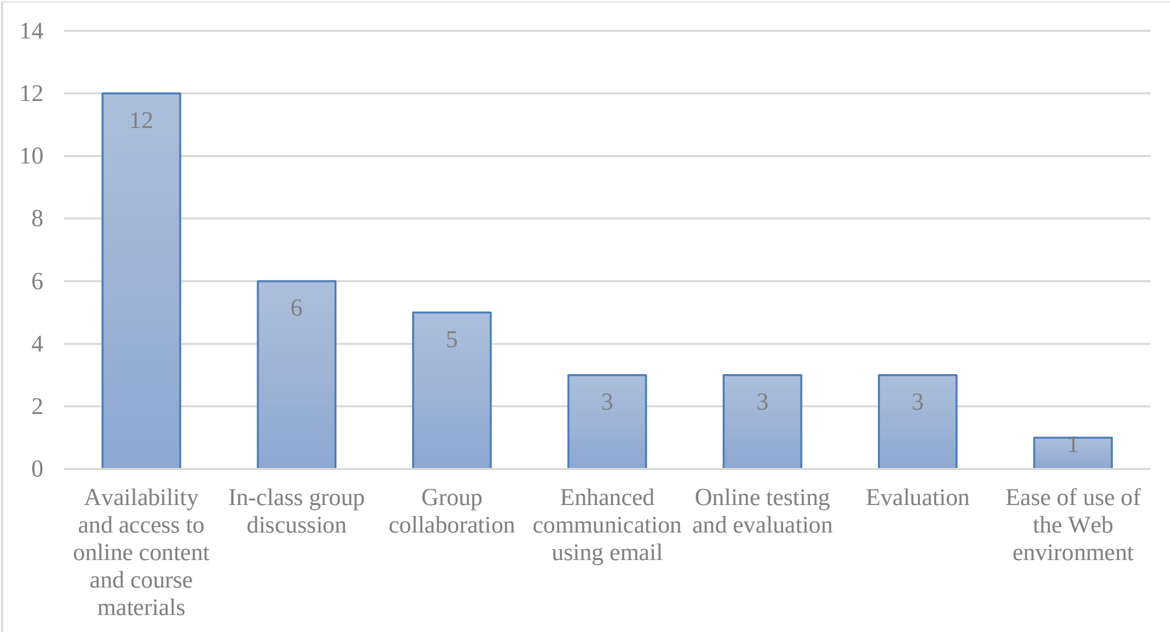

Figure 12: Which of the following have helped you improve your learning experience for the past 4 units?

When analyzing the open-ended questions, five themes emerged from the students' answers; 1) accessibility, 2) pacing, 2) use of class time, 4) motivation, and 5) teacher interactions. Even though students did not have to answer all the questions, there were enough responses to see what the advantages and disadvantages of the flipped class were according to the students. When students were asked what they found advantageous about the flipped classroom, 8 out of 48 (17%) of the responses indicated that students felt that the accessibility of the videos was beneficial. Another 13 out of 48 (27%) state that they were able to watch the videos at their own pace and as many times as the needed to understand the material. 25% (12 out of 48) of the students stated that they did appreciate the increase in class time to do more collaborative activities and labs. Out of the remaining 15 responses, most stated that they did not see any advantages to the flipped class. The last question on the survey yielded different results than the open ended questions. The open ended response indicated that students felt self-pacing and collaborative class time were the most advantageous aspects of the course. The forced response question indicates that collaboration is not as important in learning as the accessibility of the online materials. Though these responses seem to be contradicting, students answer the survey were not required to answer the forced response question. There were only 33 responses on the forced response question compared to the 48 responses for the open ended question. This indicates that several students did not answer the forced response question.

Even though many students appreciated the readily available online notes, several students identified that this accessibility was an unintentional disadvantage because they were less motivated to take notes and would often skip watching the videos. They would then fall behind in the content. Lack of motivation or being easily distracted was considered a disadvantage by 9 out 40 students (22.5%). One student commented, “I forget to watch the videos and then I'm really behind and stressed out whereas if the teacher lectures, I'm guaranteed to learn the material.” And 25 out of 40 (62.5%) of the students indicated that they did not like the fact they could not ask their teacher questions and they felt that it was more difficult to understand the concepts from a video. When asked what the disadvantages of the flipped class method were, students replied, “It is harder to understand certain concepts because you can't immediately ask questions when you have them.” “If I have a question I can't ask Mrs. Memler right then and there.” A complete list of responses is listed in Appendix C.

CHAPTER 5

DISCUSSION

Summary

The purpose of this study was to examine how well students learn physics content by using the flipped classroom, if the gender gap is reduced in a flipped classroom, and to identify students' perceptions of their learning in a flipped class environment. The flipped classroom allows students to receive instruction outside of the classroom through videos in order to use classroom time for practice, active learning strategies and increased teacher interactions to enhance their understanding of physics. It was hypothesized that the flipped classroom method would increase the conceptual knowledge of students and decrease the gender gap in physics among students.

The study's participants included 60 students in two high school honors physics classes that I taught. One class was taught fall semester and the other was taught spring semester. The units for this study consisted of the mechanics portion of the physics course; kinematics, forces, energy and momentum. I used a switch replications design to increase validity in the study. Students alternated teaching methods between consecutive units and these were compared with students from the other class. Students were administered the Force Concept Inventory at the beginning of the semester to establish a baseline of their prior knowledge. They were given the FCI as a post test and their growth was measured at the end of the study. During the experiment, students were evaluated on unit tests and these were used to compare their conceptual knowledge for each unit. At the end of the semester, students were asked to complete survey where they answered 18 Likert scale questions about their perceived learning and their experiences with the flipped classroom. The survey also included 5 open-ended responses about their experiences with the flipped classroom.

Discussion of Research Question 1

The first question that guided this study was *How does the implementation of the flipped classroom model increase student conceptual knowledge in physics?* It was hypothesized that students in a physics class would benefit from the flipped class method due to the transitioning of class time from passive learning activities, such as lecture, to active learning activities and increased collaborative group work. The results from the unit tests indicated that the flipped classroom had little effect on the conceptual knowledge gained by students in the physics class. Though the first two unit tests showed a statistically significant difference between the traditional and flipped methods, the last two tests, as well as the unit tests questions evaluated together, showed no statistical difference, nor was there a significant difference in the Mechanics Baseline Test question comparison.

Huber and Werner (2016) reviewed fifty-eight peer reviews research studies on the flipped (or inverted) classroom and found that, out of the 26 studies that focused on achievement, ten studies found no statistical difference in the performance of students who were taught using a flipped versus traditional classroom. Fifteen studies did report some evidence of increases learning and one showed decreased achievement when the flipped classroom was implemented. Another review of the literature showed there was an increase in academic achievement after implementation of the flipped classroom (O'Flaherty & Phillips, 2015). Both of these literature reviews focused on using the flipped class method in higher education and they did not review any secondary, or high school, classes. Paulson, Dr. Adriana Banu, Dr. Brian Utter and Dr. Bill Ingham of James Madison University state that they have seen their student pre-test/post-test growth increase from 20-25 % to 35% since they began flipping their college physics classes (Gorton, 2014).

The results of my study do not lend support to the research studies that showed an increase in student academic achievement. When researching current studies on implementing a flipped classroom design in the high school setting, I found results similar to that of my research. Johnson and Renner (2012) saw no differences in academic growth in high school computer science students when taught with the flipped class. Saunders (2014) and Strohmyer (2016) found no statistical differences in achievement by students in high school mathematics classes. In high school science classes, Glynn (2013), chemistry, and Bell (2015), physics, both showed no academic differences between traditional and flipped classes in their studies. When searching for flipped class and physics, there are several examples of teachers who are using the flipped class and claim to have great success, but they do not provide statistical evidence to support these claims (Thomas-Palmer, 2017; Garcia, 2017; Roberts, 2017).

Discussion of Research Question 2

The second question that guided this study was *What is the difference in conceptual gain between girls and boys when implementing the flipped classroom model?* It was hypothesized that any “gender gap”, the difference between male and female physics knowledge, will be reduced for the flipped class model. The FCI pretest showed that there was a statistical difference between males and females in their prior knowledge of physics at the beginning of the semester. The FCI posttest showed that there was not a significant difference in gain scores between genders, but since all students were taught using both traditional and flipped methods, this does not effectively evaluate the influence of teaching methods. These results imply that both males and females gained the same amount of knowledge, relative their prior knowledge, during the semester. This does raise an interesting question. If the female students had significantly less prior knowledge, yet their gain scores were not significantly different, did the flipped class method have a positive effect on their learning? This is an area where future research is needed to determine the effectiveness of the flipped class on reducing the gender gap.

There was a significant effect for teaching method with females taught using the flipped method receiving higher scores than females taught in a traditional setting. These results are consistent with the research on alternative learning methods for female physics students in non-traditional teaching environments, especially those that emphasized cooperative learning and interactive engagement methods (Docktor & Heller, 2008; Lorenzo et al., 2006; Pollack et al., 2007).

The comparison of females on unit tests, as well as both the unit test and MBT comparisons between males and females showed no statistically significant differences. In his chemistry classes, Glynn found that there was no difference on unit tests between males and females. I found no other studies that compared the academic achievement or perceptions of the flipped class with respect to gender. Active learning has been shown to decrease the gender gap in the physics classroom (Madsen, Mckagan, & Sayre, 2013; Lorenzo, Crouch, & Mazur, 2006; Shieh, Chang & Liu, 2011). The flipped class allows the teacher more time in class to engage in active learning, which may contribute to an increased academic achievement for female students. On the unit tests, males and females had no statistical differences on their performance. This may indicate that there was a reduction in the gender gap by the end of the semester, suggesting further empirical research is needed to examine the relationship between the flipped class instruction and gender.

Discussion of Research Question 3

The final question that guided this study was *How do student perceptions of their learning experiences vary between a flip classroom and a regular classroom?* It was hypothesized that students would find the flipped classroom more engaging than the traditional classroom and that they would feel that they learned more from the flipped teaching method. The results of the Likert survey showed that 83% of the students preferred the traditional method of teaching over the flipped class and only 19% of the students found the flipped classroom to be more engaging than a traditional class setting. Though students had some positive comments and could identify advantages to the flipped classroom, they preferred traditional teaching methods.

In their review of the research, Huber and Werner (2016) found that 33 out of 41 studies found that students perceive the flipped teaching method positively and the other eight reported negative perceptions to the flipped class. The inverted class is a newer teaching strategy that many students have yet to experience in their education. Some of the students indicated that they say benefits to the flipped class even if they preferred a traditional learning environment and other students had difficulty transitioning to a new learning style. Strayer (2012) had similar results, indicating that students did not like the online lectures, but they appreciated the alternative learning experiences offered to them in class. Though my study had similar results for academic achievement as Bell (2015) and Strohmyer (2016), both of these studies show positive perceptions of the flipped class by students.

Limitations

When I first began this study, I was excited at the prospect of implementing a new teaching method that would benefit the students. Creating videos and new activities that would complement the flipped method can be time consuming for the teacher. The extra work would be a good trade-off for increased learning by the students. This study did not show evidence of any significant advantage of using the flipped class over traditional teaching methods.

There were several drawbacks to the study that may have influenced my results. Because of the schedule at my school, I had to divide the study into two different semesters. Though the switching replications design should allow this study to be conducted without the classes being simultaneously taught, there are small differences that may affect the outcomes. Because of the different time of year, school holidays and breaks fell during different units, which may have caused some issues. The units were taught over the same number of days, but the fall semester students had Thanksgiving break during the energy unit and spring semester had Spring Break during the Newton/forces unit. This discontinuity may have had a small effect on the students. Spring semester also has more sporting events, which causes some students to miss class more often and impending summer becomes a distraction to many students, especially the seniors.

The results showed that, though there was no overall statistical difference between the students in the two teaching methods, the fall semester students did not perform as well as the spring students on the kinematics and forces unit tests, regardless of teaching method. All students taking Honors Physics at my high school must have a prerequisite or co-requisite course of Honors Trigonometry. Since the school is on a block schedule, the scheduling program considers taking a course during the same year as a co-requisite course, even though the student(s) may have Honors Physics first semester and Honors Trigonometry second semester. This may have allowed the spring semester students to have more math and problem solving skills than students who were enrolled in the fall Honors Physics course.

It was hypothesized that any “gender gap”, the difference between male and female physics knowledge, will be reduced for the flipped class model. The FCI pretest showed that there was a statistical difference between males and females in their prior knowledge of physics at the beginning of the semester. The Hake gain, though preferred for analyzing FCI pre/post data, does have limitations. According to Miller et al. 2010, normalized gain "implicitly assumes that losses are zero" (p. 232) and does not account for students who score lower on the post-test and on the pre-test. These losses could "represent actual conceptual losses, or... result from correct guesses on the pre-test that, by chance, became incorrect on the post-test" (p. 232) and “losses are potentially weighted much more heavily than gains” (p. 229). Several students in this study scored worse on the posttest than the pretest which may have affected the gain scores.

In today's class, many students are not intrinsically motivated to learn at a deeper knowledge. Students are competing for scholarships and placement at the college of their choice. At my school, students are very competitive and, thus, grade driven. Students, especially juniors and seniors, want to learn what will be on the test to ensure that they will get a good grade. Because of this, students do not want to deviate from the traditional method of teaching. As one student stated "If the teacher lectures, I'm guaranteed to learn the material." Students who are already motivated to learn will take advantage of the online lectures, while there are limited checks to ensure that unmotivated students are accessing the information in a timely and productive manner.

Students overwhelmingly did not like the flipped class method. Since I began the year teaching the first four units with traditional teaching methods, students may have become comfortable with my teaching style and did not like the change to a new method in the middle of the semester. Students often have trouble adapting to new technologies and teaching methods, especially after the semester began, and this can be uncomfortable for students (Hutchings & Quinnery, 2015). If the students had been introduced to the flipped method at the beginning of the year, they may have had a different perception.

Another factor that may have contributed to the non-significant findings in achievement, as well as the perceived learning outcomes, could be my teaching style and my commitment to see all students succeed. As a teacher who is dedicated to my students, I push students to seek out tutoring with me and/or peers when they are struggling in class, as well as extra learning opportunities (quiz corrections, resubmitting assignments). This did not change for my study. Students who may have struggled in the flipped class could have taking these learning opportunities to increase their understanding, which may have affected my results. Also, as a teacher who was new to the flipped class method, there was a learning curve for me which may have been a contributing factor to the overall success of the flipped learning experience for the students.

Several of the responses to the open ended questions discussed the lack of interactions with the teacher and the inability to ask questions when they arose. In his research, Strohmyer (2016) discusses the importance of time to engage in questioning during class. “Questioning is an important part of both accessing experts” and “results in connections of basic and advanced knowledge” (p. 186). The flipped class does allow for more class time to be used for active learning, but students missed out on the immediate interaction with their teacher during the dissemination of information.

Implications and Recommendations

Flipped teaching has grown in popularity over the last few years, but there are still few research studies that have been done on its academic benefits. This study was developed with the hypothesis that the flipped class would increase conceptual knowledge of physics. Though my findings did not support this hypothesis, it did show that the flipped class is an alternative to traditional lecture classes. I found only one study that involved the flipped class and high school physics classes, though there were several studies in mathematics, computer science and chemistry. The research in this study adds to the small amount of literature that has been conducted in the high school setting. More research is needed to evaluate the effectiveness of the flipped class.

An area of research that is still lacking is the effects of alternate teaching strategies for females in the physics class. Research on the flipped class and how it can benefit girls in STEM fields could provide many benefits to teachers and students in these areas. Studies that show how the online lectures allow for deeper understanding or help to eliminate misconceptions are needed. Does the flipped class have any real effect on the increased achievement that was found in several studies, or are the active learning activities the underlying cause of the increased knowledge. Is it necessary to flip a class to create an interactive learning environment?

It is essential for a teacher who is implementing the flipped class in their curriculum to take the time to create a course that will benefit the students. Holding the students accountable is crucial. This is an area that could have been improved upon in my study. MOODLE and other CMS or LMS platforms have ways to track the students. In MOODLE, I create lessons that required the students to watch a video and then answer questions to assess comprehension (Appendix F). MOODLE only tracks if the student opened the video file, not whether the entire video was viewed before moving on to the questions. I could not definitively state that the students watched all the videos thoroughly. New ways to take advantage of the flipped class are being developed. A new technology that will enhance the flipped experience is EdPuzzle. This website allows teachers to upload videos (or use videos from other sources) and embed questions into the video. There is a setting that also prevents students from skipping through the video to the next question. This helps to ensure that the student watches the entire video.

When creating the flipped videos, teachers need to create videos that are limited in their time. The average sustained attention span of a teenager is around 20 minutes (Cornish & Dukette, 2009). Videos that last longer than 15 or 20 minutes will lose the interest of the student. Also, engaging videos will help to keep the interests of the students. Try to think of questions that students might ask and address those in the recorded lecture. It is important that the video lectures cover material that can easily be understood by the student without too much in depth comprehension. If the content requires deeper explanations that will illicit questions from the students, it is best that the material be presented in class.

My students had a difficult time adjusting to the flipped class. If I were to redo the study and what I plan for my future courses, I would introduce the online teaching to the students in the beginning. Using the videos as review or assignments to preview material in shorter videos at the beginning of the year will allow the students to become familiar with the learning digitally. As the semester progresses, the class structure can move to more of a flipped and active learning environment. And, as with all teaching strategies, it is essential that the teacher does not use let the flipped class become redundant and stale. Student need variety to sustain their interest.

Conclusion

Science teachers in the State of Georgia will soon be required to implement a new curriculum based on The Next Generation Science Standards (NGSS). The NGSS are the new national standards for science that identify content, science, and engineering practices necessary for all students in grades K-12 (Achieve, Inc., 2013). "As emphasized in the [NGSS] *Framework*, an active learning of scientific practices is critical, and takes time. A focus on these practices, rather than on content alone, leads to a deep, sustained learning of the skills needed to be a successful adult, regardless of career choice. We must teach our science students to *do something* in science class, not to memorize facts" (NGSS, para 6).

The NGSS reevaluate how teachers and students interact with each other in the classroom. The standards support learning through a three-dimensions: 1) Practices, 2) Crosscutting content and 3) Disciplinary core ideas. The focus for teachers is to engage the students in scientific practices while learning the content and connecting the concepts to broad themes such as energy and matter, structure and function, and stability and change. By implementing the practices of scientists and engineers, it shifts the responsibility of learning from the teacher to the student (APT, 2015; Kawasaki, 2015; Laxton, 2016).

The flipped class model gives the teacher the time and flexibility to create a student centered learning experience. The basic concepts that are introduced in the videos outside of class are the foundation for active learning activities in the class. The traditional class model uses class time to lecture, leaving little time for students to plan and carry out experiments. In traditional science classes, labs have been designed for students to follow directions to achieve a predicted outcome rather than allowing students to collaborate, research and design their own investigations. The flipped classroom uses the in class time for students to behave like scientists. New and innovative teaching styles are great for an ever-changing population and teachers must be willing to adapt to new standards and different teaching styles.

More research is needed to determine if the flipped class is beneficial as a stand-alone teaching method or if it is a tool that teachers can use to diversify their class. Though this study does not show any statistical benefits to using the flipped method, using this method along with traditional teaching methods can benefit some students. It is important to identify the needs of your students and create a classroom environment that will benefit all students. This includes using alternate learning strategies, such as the flipped classroom, and traditional teaching methods.

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Appendix A: Guided Notes

Collisions

Consider 2 objects speeding toward each other. When they collide......

Due to Newton's 3rd Law the FORCE they exert on each other are _________ and ___________.

The _________ of impact are also equal.

Therefore, the _________ of the 2 objects colliding are also _________!

Mathematically:

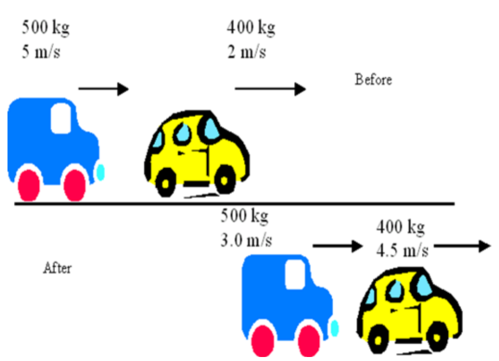
If the Impulses are equal then the _________ are also equal!

Mathematically:

$$\sum p_{before} = \sum p_{after}$$

Momentum is conserved!

Law



Appendix B: Student Survey

Student Perceptions of The Flipped Classroom Survey

1. Rate each item on the scale provided to indicate your agreement.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The flipped classroom is more engaging than a traditional lecture centered classroom.					
I would not recommend a class that was taught using the flipped classroom to a friend.					
The flipped classroom allows me to collaborate with my other students more.					
I liked watching the lessons on video.					
I am more motivated to learn physics in the flipped classroom.					
I learned more physics when taught using the flipped classroom.					
I liked using the guided notes when watching the lesson videos.					
I always watched the video lessons prior to class.					
I watched the video lessons more than the once during the unit.					
When watching the video lessons, I would stop and rewind when I did not understand a concept.					
The MOODLE quizzes at the end of the videos helped me to evaluate what I had learned.					
I did not like taking the MOODLE quizzes online.					
I did not watch all the videos required for the unit.					
I would prefer a traditional teacher led lecture than a video lecture.					

The flipped classroom allowed me to have more meaningful interactions with Ms. Memler.					
The assignments and projects I have worked on in this course deal with real life applications and information.					
My test grades accurately reflect my learning during the flipped classroom units.					
My test grades accurately reflect my learning during the Traditional Classroom units.					
Which of the following have helped you improve your learning experience for the past 4 weeks? (you may pick more than one) __a. Availability and access to online content and course materials __b. Enhanced communication using email, online discussion, MOODLE __c. Online testing and evaluation __d. Evaluation, feedback using the quiz and grade tools. __e. Ease of use of the Web environment __f. In-class group discussion __g. Group collaboration __h. Working on the assignments and class work by myself					

Please answer the following questions about your experience in a flipped classroom setting.

2. What are the advantages of the flipped classroom?

3. What are the disadvantages of the flipped classroom?

4. Would the flipped classroom be useful for other subjects? Why or why not?

5. What improvements would you recommend to improve learning in the flipped classroom?

6. Please state any other comments you wish to make about the flipped classroom.

Appendix C: Responses to Student Survey

Student Perceptions of the flipped classroom Survey					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The flipped classroom is more engaging than a traditional lecture centered classroom.	12	18	9	7	3
I would not recommend a class that was taught using the flipped classroom to a friend.	7	7	13	14	10
The flipped classroom allows me to collaborate with my other students more.	10	15	14	7	3
I liked watching the lessons on video.	8	12	9	14	6
I am more motivated to learn physics in the flipped classroom.	13	16	13	2	5
I learned more physics when taught using the flipped classroom.	13	14	11	7	4
I liked using the guided notes when watching the lesson videos.	2	10	9	18	9
I always watched the video lessons prior to class.	2	13	5	19	9
I watched the video lessons more than the once during the unit.	14	17	6	10	4
When watching the video lessons, I would stop and rewind when I did not understand a concept.	1	6	9	19	15
The MOODLE quizzes at the end of the videos helped me to evaluate what I had learned.	12	11	9	12	7

I did not like taking the MOODLE quizzes online.	5	3	15	14	11
I did not watch all the videos required for the unit.	13	13	6	12	4
I would prefer a traditional teacher led lecture than a video lecture.	1	0	7	17	26
The flipped classroom allowed me to have more meaningful interactions with Ms. Memler.	8	18	16	4	2
The assignments and projects I have worked on in this course deal with real life applications and information.	6	2	18	13	11
My test grades accurately reflect my learning during the flipped classroom units.	2	8	15	14	8

What are the advantages of the Flipped Classroom?
I like to watch videos so I pay attention more.

You can go your own pace.

Nothing

You can go at your own pace

N/A

I liked learning at home and having the quizzes

I had access of the lesson at any given moment. I was able to go at my own pace. I was able to replay parts of the lecture I missed.

None

You can watch the videos whenever you have free time and the information is easy to understand and follow

An advantage would be that the students could learn the material at home and have more time to practice it in class. The class would also get ahead in learning all the material.

Allows us to hear the lecture multiple times if needed in the flipped classroom you as the student have the ability to rewind and get some note you might have missed where as you can do that without interrupting others

It might be easier for some people to learn by themselves online, and be more concentrated.

I did not like flipped classroom, it didn't help me at all.

You can go back and hear the information again

You can rewatch lectures.

Allows us to hear the lecture multiple times if needed

You can go back and hear the information again

I like to watch videos so I pay attention more.

You can watch the videos whenever you have free time and the information is easy to understand and follow

"I had access of the lesson at any given moment.
I was able to go at my own pace.
I was able to replay parts of the lecture I missed.
"
The advantages of the flipped classroom include being able to watch the videos at my own pace and rewinding when I didn't understand a topic. It was nice to follow guided notes too and being able to go back the videos at any time during the unit.

Makes kids more involved cause it new
You can rewatch lectures.

In the flipped classroom you as the student have the ability to rewind and get some note you might have missed where as you can do that without interrupting others

None

None

Nothing

You can rewind

I liked learning at home and having the quizes

You can go your own pace.

Learn on your own.

N/A

More time in class to work on labs

You can go at your own pace

I did not like flipped classeroom, it didn't help me at all.

An advantage would be that the students could learn the material at home and have more time to practice it in class. The class would also get ahead in learning all the material.

It might be easier for some people to learn by themselves online, and be more concentrated.

Easier to learn and comprehend the material

more time in class to review topics you dont understand

More class room time for labs

none

Not sure

I can learn the lessons in a quiet environment when I'm comfortable.
Can watch them more than once. See them if your out of class.

Get to see the material more times than once

There are none. Most people learn traditionally and the flipped classroom actually affects them in a negative way.

At home, there are little distractions, and you focus more on learning.

Less time doing notes in class allowed for more time to do fun things to learn in class.

Less time doing notes in class allowed for more time to do fun things to learn in class.

More time in class to practice.

more inreractive

You can rewind if you missed anything.

nothing

the one advantage of a flipped classroom is the easy access to the information online.

there are none, I would have liked the flipped classroom if it wasn't my teacher in the video, it would be nice to have a fresh face to learn from.

it was online

You can watch the videos when you want to.

You get more time to do practice in the classroom.

You get more time to do practice in the classroom.

I found no advantages of the flipped classroom.

What are the disadvantages of the Flipped Classroom?
we cant ask questions if needed

no personal interaction, you can't stop an online lecture to ask the teacher a question

If I have to watch a video at home I cant ask a question.

If i have questions during the video, I cannot ask my teacher any questions until the next day in class. and then i could forget the questions i was going to ask

"If I had a question about a concept, I was not able to ask Mrs. Memler right away.
The problems that were examples that showed how to solve something were not neat, so I couldn't comprehend it. "

Some of the disadvantages of the flipped classroom include not being able to ask questions about the topics being discussed and communicating with my peers about the topic when I needed minimal information.

Some people don't like change

"You just practice in class and it doesn't accurately show what one might be capable of.

if you dont understand somthing you can ask questions on what you dont get and you have you "save" your questions for next time when you the teacher again and in some cases you will forget your question than you wont fully understand the unit and wont be able to get a good grade like you wanted
Al
I

No one on one contact

Can't ask teacher questions

I cannot ask questions

You can't ask questions.

Choose not to do it.

Boring and I almost have no motivation to take the time out of doing homework to take new notes from a video quiz.

I felt like I didn't understand the topic when we would do labs in class because it was hard to learn off a 20 minute video. It was hard to take a quiz on a lecture we had just listened to and make a good grade.

The teacher and students are not physically there with you so you can't have questions answered as you need them, which is something I like to have available.

You can't ask questions

A disadvantage would be that the student would have problems understanding the material. The student won't be able you ask the teacher questions until the next day.

They may also get questions wrong in the quiz at the end of the video.

Sometimes it's hard to comprehend things if its not hands on.

Less independant work

if you have questions you cant ask

I didn't understand the material as much

Can't ask questions when it's a video

Hard to follow

Some students didn't do the videos so they had no clue what is going on.

Can't ask a computer questions.

May not understand the material as well

People don't learn as well as they would during a lecture, they can't ask questions.

You can't ask questions while learning the material.

Quizzes after videos sometimes were not working properly so it didn't always show what I learned.

No teacher at home to answer questions

more prone to losing focus

You can't ask questions.

the teacher isnt there to help with things you dont understand.

you sometimes need more explanation, which you can't get from the videos.

It is harder to understand certain concepts because you can't immediately ask questions when you have them.
.
I forget to watch the videos and then I'm really behind and stressed out whereas if the teacher lectures, I'm guaranteed to learn the material.

If I have a question I can't ask Mrs. Memler right then and there.

Would the Flipped Classroom be useful for other subjects? Why or why not?
Its not useful at all

yes, in history classes due to no use of math

Yes, for some subjects you may need to ask less questions or just learn the basic content and then ask deeper questions later in class.

It could work for history classes and language arts because those subjects are mostly conceptual and don't involve a lot of math

I feel that the flipped classroom is appropriate for the subjects we learned and that it is best to use it sparingly so that students can have a more hands-on approach to the unit.

Maybe I don't knos

Possibly. Depends on what it's about

some subjects it would alright and others it wouldnt, math, and history would be alright with flipped classroom but with a class like lit. it wouldnt so much cause if you a student like me, you wont get all of it

No

Nope

No because you can't get one on one help

Yes because if someone's absent they can still have the class

yes because I could learn better

Yes because people might understand the content more because they can rewind.

No. Gives people choice to do it or not.

No, because it wasn't effective for this one.

Not useful. A teacher should be there to lecture the class so students can ask questions and intereact with the teacher so they will better understand before they do labs in class.

It would not be useful for me for other subjects because I like to have the availability of asking questions right when I have him. Also, I don't focus well when I work at home.

No it's not helpful

I don't really know.

No, not for me because it's harder for me to learn alone.

Yes because easier to comprehend

yes, it gives more time in the classroom and youre able to do notes at your own speed
I would not because other subject require in class teaching so I can understand the material

maybe

Maybe not sure really

It would be good for history because that's straight out of the books. Things like math would be bad because you can't ask questions about the process.

I like traditional classes better for all subjects.

Probably not

No

Yes, I have taken online classes similar to the flipped classroom and I performed well in them.

Yes, because it would allow time to do more things like in Ap computer science. In that class it would allow more time to do labs and worksheets in class.

math it is used a lot in physics

yes, some of them are less interesting than physics
I don't think it is useful for any subjects.

no because i think science is easy.

I think that this was the hardest subject the flipped classroom could work in

I don't think so because students get easily distracted when watching the videos.

History probably because you could have more discussions about topics instead of spending all of the time taking notes.
.
The flipped classroom is not useful for any subject. When you have to learn the material by yourself, you can't ask questions if you don't understand and then you get confused and behind.

What improvements would you recommend to improve learning in the Flipped Classroom?
remove it

maybe do a live video where students can chat the teacher during the lecture

Have a video then a group discussion about that video. Also when doing problems give the students plenty of time to do each one and then have them go over them with a group.

Make the moodle quizzes multiple choices because if a question requires you to type the answer, it would count it wrong if there is a spelling error

I would prepare anticipated questions and work a little slower in order for students to comprehend all of the topics.

I don't really know

Not doing it.

have a flipped classroom for every unit and a tradition classroom for every unit as well so if you dont get it you can just look at the flipped one or traditional one

Can improve

None

one on one help

Interactive lectures where students can ask questions or longer more elaborate video notes with easier quizes that only count for a completion grade (if you score over 70)

No quiz

I don't have any improvements.

Maybe I would put multiple choice for the answer choices on the quiz. I would do this because sometimes when we typed in the answers it would count it as wrong even if it was right.

Live flipped classrooms where students get on at a certain time and watch the teacher teach live.

Have quizzes that function properly and are fun to do.

slightly more structure
To have videos come from another source
Nothing. I liked it a lot.

Please state any other comments you wish to make about the Flipped Classroom.

I feel that the flipped classroom is great when used sparingly and the quizzes were good for retaining information but a more hands-on approach is a method I personally would emphasize more.

not all students will have computer access so they wont be able to veiw the lessons on the computer

I like that you made the videos instead of us having to search them, because then we would all have learned different techniques.

I think it's good for some people but maybe not so much for others. Maybe there could be an option whether to learn it online or in the classroom.

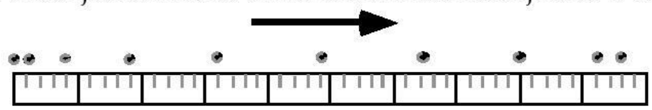
I have been in a few other classes that used the flipped classroom and personally I find it harder to learn that way.

I feel that our class as a whole performed worse while engaged in the flipped classroom setting. There is no room for error if we stick to the traditional classroom.

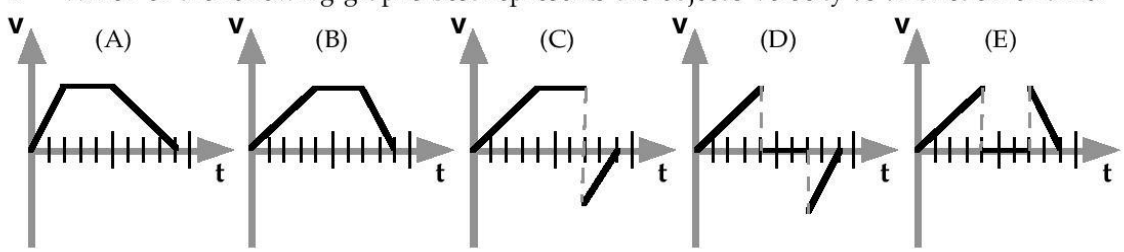
Appendix D: Mechanics Baseline Test

Mechanics Baseline Test

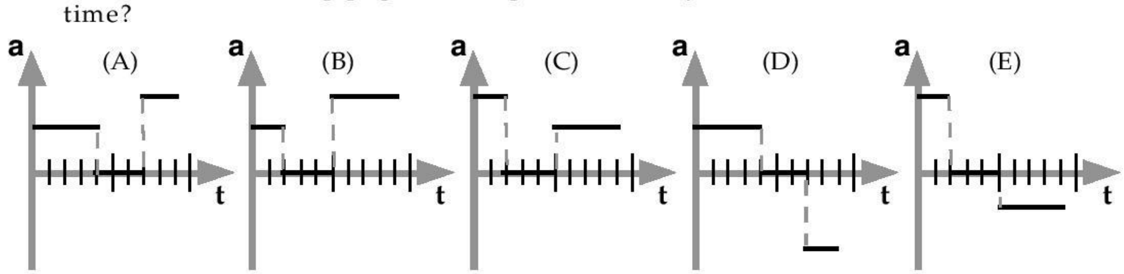
Refer to the diagram below when answering the first two questions. This diagram represents a multiflash photograph of an object moving along a horizontal surface. The positions as indicated in the diagram are separated by equal time intervals. The first flash occurred just as the object started to move and the last flash just as it came to rest.



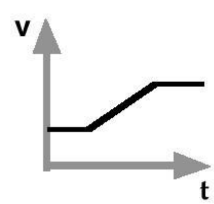
1. Which of the following graphs best represents the object's velocity as a function of time?

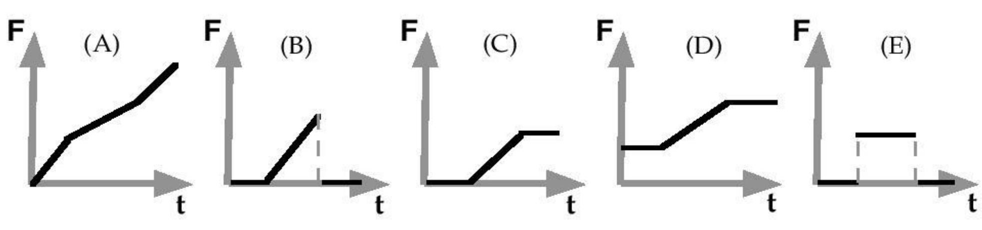


2. Which of the following graphs best represents the object's acceleration as a function of time?



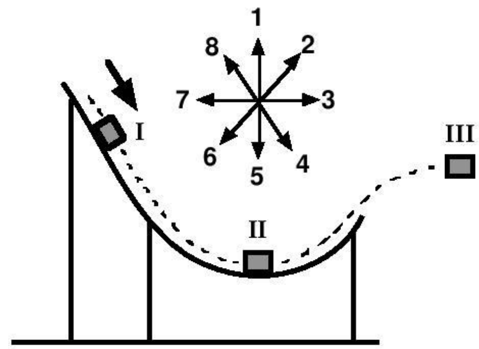
3. The velocity of an object as a function of time is shown in the graph at the right. Which graph below best represents the net force *vs* time relationship for this object?





Refer to the diagram on the right when answering the next three questions.

The diagram depicts a block sliding along a frictionless ramp. The eight numbered arrows in the diagram represent directions to be referred to when answering the questions.



4. The direction of the acceleration of the block, when in position I, is best represented by which of the arrows in the diagram?

(A) 1 (B) 2 (C) 4 (D) 5
(E) None of the arrows; the acceleration is zero.

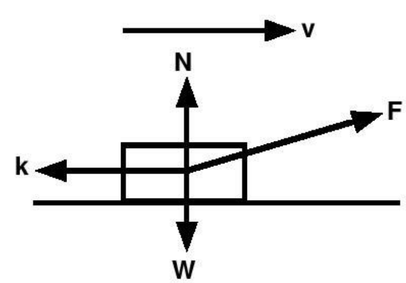
5. The direction of the acceleration of the block, when in position II, is best represented by which of the arrows in the diagram?

(A) 1 (B) 3 (C) 5 (D) 7
(E) None of the arrows; the acceleration is zero.

6. The direction of the acceleration of the block (after leaving the ramp) at position III, is best represented by which of the arrows in the diagram?

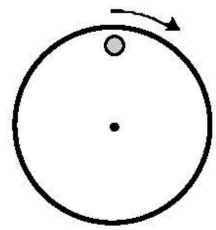
(A) 2 (B) 3 (C) 5 (D) 6
(E) None of the arrows; the acceleration is zero.

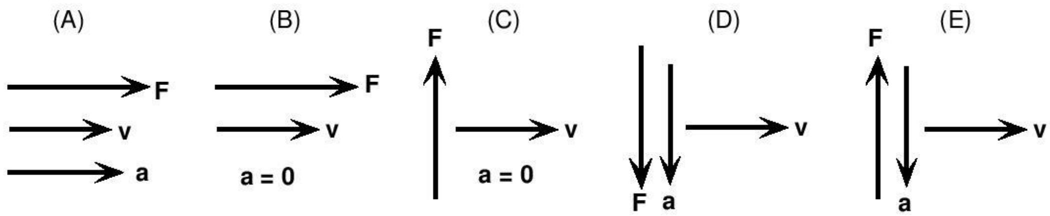
7. A person pulls a block across a rough horizontal surface at a **constant speed** by applying a force **F**. The arrows in the diagram correctly indicate the directions, but not necessarily the magnitudes of the various forces on the block. Which of the following relations among the force magnitudes W, k, N and F **must be true**?



(A) F = k and N = W (B) F = k and N > W
(C) F > k and N < W (D) F > k and N = W
(E) None of the above choices

8. A small metal cylinder rests on a circular turntable, rotating at a constant speed as illustrated in the diagram at the right. Which of the following sets of vectors best describes the velocity, acceleration, and net force acting on the cylinder at the point indicated in the diagram?

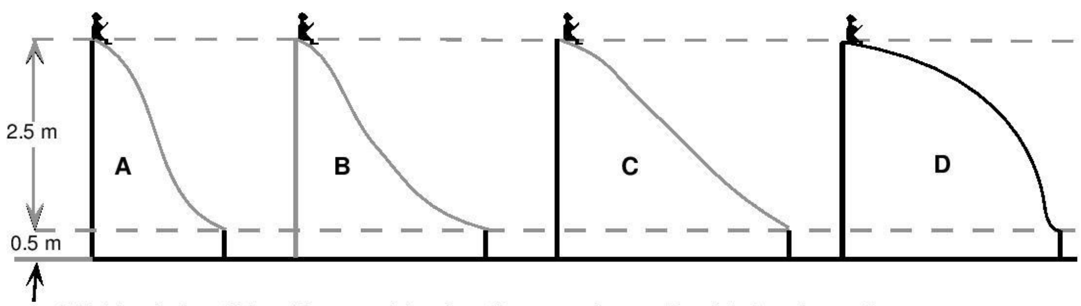




9. Suppose that the metal cylinder in the last problem has a mass of 0.10 kg and that the coefficient of static friction between the surface and the cylinder is 0.12. If the cylinder is 0.20 m from the center of the turntable, what is the maximum speed that the cylinder can move along its circular path without slipping off the turntable?

(A) $0 < V \leq 0.5$ m/s (B) $0.5 < v \leq 1.0$ m/s
(C) $1.0 < v \leq 1.5$ m/s (D) $1.5 < v \leq 2.0$ m/s
(E) $2.0 < v \leq 2.5$ m/s

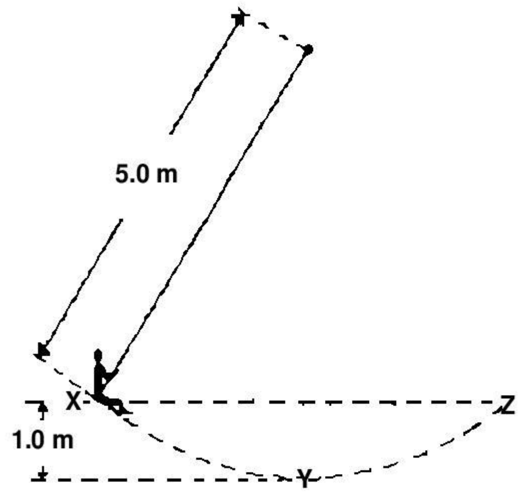
10. A young girl wishes to select one of the **frictionless** playground slides illustrated below to give her the greatest possible speed when she reaches the bottom of the slide.



Which of the slides illustrated in the diagram above should she choose?

(A) A (B) B (C) C (D) D
(E) It doesn't matter; her speed would be the same for each.

Refer to the diagram below when answering the next two questions.



X and Z mark the highest and Y the lowest positions of a 50.0 kg boy swinging as illustrated in the diagram to the right.

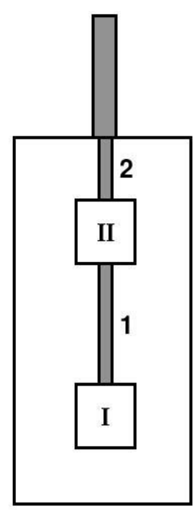
11. What is the boy's speed at point Y?

(A) 2.5 m/s (B) 7.5 m/s
(C) 10. m/s (D) 12.5 m/s
(E) None of the above.

12. What is the tension in the rope at point Y?

(A) 250 N (B) 525 N
(C) 7×10^2 N (D) 1.1×10^3 N
(E) None of the above.

Refer to the diagram below when answering the next two questions.



Blocks I and II, each with a mass of 1.0 kg, are hung from the ceiling of an elevator by ropes 1 and 2.

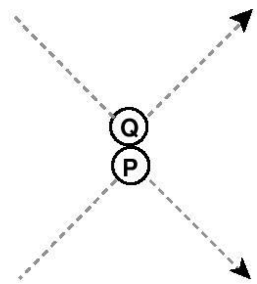
13. What is the force exerted by rope 1 on block I when the elevator is traveling upward at a constant speed of 2.0 m/s?

(A) 2 N (B) 10 N (C) 12 N
(D) 20 N (E) 22 N

14. What is the force exerted by rope 1 on block II when the elevator is stationary?

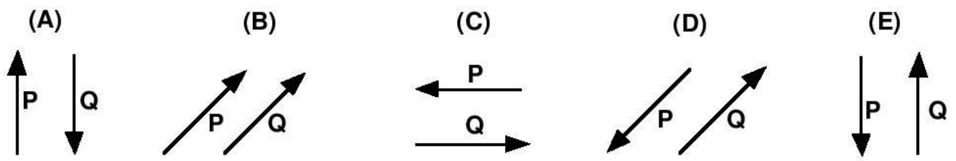
(A) 2 N (B) 10 N (C) 12 N
(D) 20 N (E) 22 N

Refer to the following diagram when answering the next two questions.

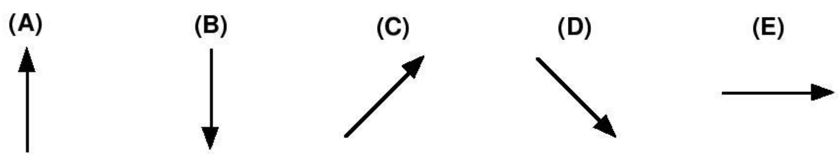


The diagram to the right depicts the paths of two colliding steel balls, P and Q.

15. Which set of arrows best represents the direction of the change in momentum of each ball?



16. Which arrow best represents the direction of the impulse applied to ball Q by ball P during the collision?



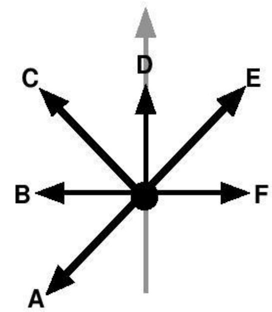
17. A car has a maximum acceleration of 3.0 m/s^2. What would its maximum acceleration be while towing a second car twice its mass?

(A) 2.5 m/s^2 (B) 2.0 m/s^2 (C) 1.5 m/s^2 (D) 1.0 m/s^2 (E) 0.5 m/s^2

18. A woman weighing 6.0×10^2 N is riding an elevator from the 1st to the 6th floor. As the elevator approaches the 6th floor, it decreases its upward speed from 8.0 m/s to 2.0 m/s in 3.0 s. What is the average force exerted by the elevator floor on the woman during this 3.0 s interval?

(A) 120 N (B) 480 N (C) 600 N (D) 720 N (E) 1200 N

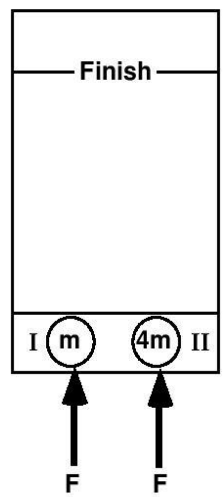
19. The diagram at right depicts a hockey puck moving across a **horizontal, frictionless** surface in the direction of the dashed arrow. A constant force **F**, shown in the diagram, is acting on the puck. For the puck to experience a net force **in the direction of the dashed arrow**, another force must be acting in which of the directions labeled **A, B, C, D, E** ?



(A) **A** (B) **B** (C) **C** (D) **D** (E) **E**

Refer to the diagram below when answering the next three questions.

The diagram depicts two pucks on a frictionless table. Puck II is four times as massive as puck I. Starting from rest, the pucks are pushed across the table by two **equal** forces.

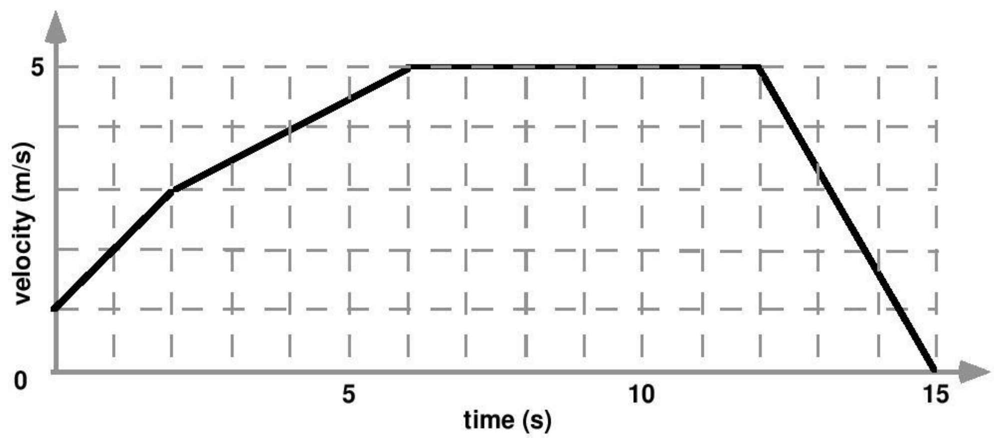


20. Which puck will have the greater kinetic energy upon reaching the finish line?
    (A) I (B) II
    (C) They both have the same amount.
    (D) Too little information to answer.

21. Which puck will reach the finish line first?
    (A) I (B) II
    (C) They will both reach the finish line at the same time.
    (D) Too little information to answer.

22. Which puck will have the greater momentum upon reaching the finish line?
    (A) I (B) II
    (C) They will both have the same momentum.
    (D) Too little information to answer.

Refer to the following graph of velocity *vs* time when answering the next three questions.



The graph represents the motion of an object moving in one dimension.

23. What was the object's average acceleration between t = 0 s and t = 6.0 s?

    (A) 3.0 m/s^2 (B) 1.5 m/s^2 (C) 0.83 m/s^2 (D) 0.67 m/s^2

    (E) None of the above.

24. How far did the object travel between t = 0 s and t = 6.0 s?

    (A) 20. m (B) 8.0 m (C) 6.0 m (D) 1.5 m

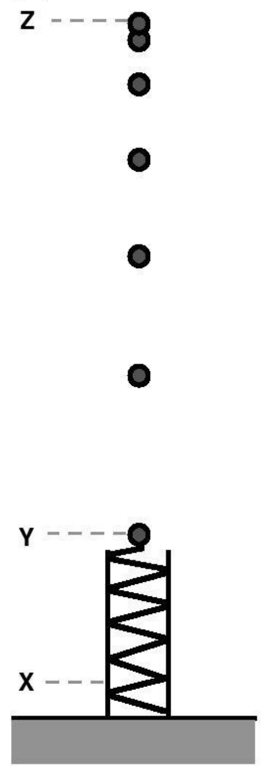
    (E) None of the above.

25. What was the average speed of the object for the first 6.0 s?

    (A) 3.3 m/s (B) 3.0 m/s (C) 1.8 m/s (D) 1.3 m/s

    (E) None of the above.

Refer to the diagram in the right margin to answer the following question.



The figure represents a multiflash photograph of a small ball being shot straight up by a spring. The spring, with the ball atop, was initially compressed to the point marked X and released. The ball left the spring at the point marked Y, and reaches its highest point at the point marked Z.

26. Assuming that air resistance is negligible;
    - (A) The acceleration of the ball was greatest just before it reached point Y (still in contact with the spring).
    - (B) The acceleration of the ball was decreasing on its way from point Y to point Z.
    - (C) The acceleration of the ball was zero at point Z.
    - (D) All of the above responses are correct.
    - (E) The acceleration of the ball was the same for all points in its trajectory from points Y to Z.

Appendix E: Force Concept Inventory

Revised form 081695R

Force Concept Inventory

Originally published in *The Physics Teacher,* March 1992

by

David Hestenes, Malcolm Wells, and Gregg Swackhamer

Revised August 1995

by

Ibrahim Halloun, Richard Hake, and Eugene Mosca

The Force Concept Inventory (FCI) is a multiple-choice "test" designed to assess student understanding of the *most basic* concepts in Newtonian mechanics. The FCI can be used for several purposes, but the most important one is to *evaluate the effectiveness of instruction*.

For a full understanding of what has gone into development of this instrument and how it can be used, the FCI papers (refs. 1, 2) should be consulted, as well as: (a) the papers on the FCI predecessor, the Mechanics Diagnostic Test (refs. 3, 4), (b) the paper on the Mechanics Baseline Test (ref. 5), which is recommended as an FCI companion test for assessing quantitative problem solving skills, and (c) Richard Hake's paper (ref. 6) on data collection on university and high school physics taught by many different teachers and methods across the U.S.A.

Refs. 1-5 are online at http://modeling.asu.edu/R&E/Research.html Ref. 6 is online as ref. 24 at http://www.physics.indiana.edu/~hake.

References

1. D. Hestenes, M. Wells, and G. Swackhamer (1992). Force Concept Inventory, *The Physics Teacher* **30**, 141-151.
2. D. Hestenes and I. Halloun (1995). Interpreting the Force Concept Inventory, *The Physics Teacher* **33**, 502-506.
3. I. Halloun and D. Hestenes (1985). The initial knowledge state of college physics students. *Am. J. Phys.* **53**, 1043-1055.
4. I. Halloun and D. Hestenes (1985). Common sense concepts about motion, *Am. J. Phys.* **53**, 1056-1065.
5. D. Hestenes and M. Wells (1992). A Mechanics Baseline Test, *The Physics Teacher* **30**, 159-166.
6. R. Hake (1998). Interactive-engagement vs. traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses. *Am. J. Phys.* **66**, 64-74.

Teacher: these are suggested directions to give your students:

Your participation is voluntary, and encouraged.

Do ***not*** *write anything on this questionnaire.*

Mark your answers on the scantron

Make ***only one*** *mark per item.*

Do ***not*** *skip any question.*

Avoid guessing. Your answers should reflect what ***you*** *personally think.*

On the scantront:

Use a ***No. 2 pencil****, and follow marking instructions.*

Fill in your name and class period.

Fill in the "Exam No." given by your teacher (if any).

Plan to finish this questionnaire in 30 minutes.

Notes to the Teacher:

* The FCI is closed-book, no notes, no equations.
* Most important! to maintain security, please don't call it the *Force Concept Inventory*; rather, give it another name (ex. mechanics survey, big force diagnostic), or no name.
* Use the FCI in its entirety, since the force concept is a unified concept.
* Consider making it count for a grade or extra credit, so that students will take it seriously.
* Collect the test and destroy it, or keep it under lock and key, so that it doesn't get into student files.
* Don't discuss the questions with students.
* Don't photocopy this page or the first page.
* If you need advice, contact the AMTA Executive Officer: visit http://modelinginstruction.org

Thank you for your cooperation.

1. Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:
   (A) about half as long for the heavier ball as for the lighter one.
   (B) about half as long for the lighter ball as for the heavier one.
   (C) about the same for both balls.
   (D) considerably less for the heavier ball, but not necessarily half as long.
   (E) considerably less for the lighter ball, but not necessarily half as long.

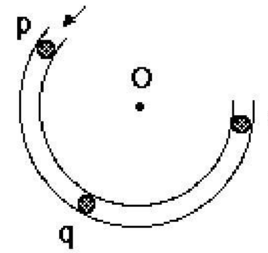
2. The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation:
   (A) both balls hit the floor at approximately the same horizontal distance from the base of the table.
   (B) the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
   (C) the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
   (D) the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
   (E) the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.

3. A stone dropped from the roof of a single story building to the surface of the earth:
   (A) reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
   (B) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.
   (C) speeds up because of an almost constant force of gravity acting upon it.
   (D) falls because of the natural tendency of all objects to rest on the surface of the earth.
   (E) falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

4. A large truck collides head-on with a small compact car. During the collision:
   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car does not exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (5 and 6).

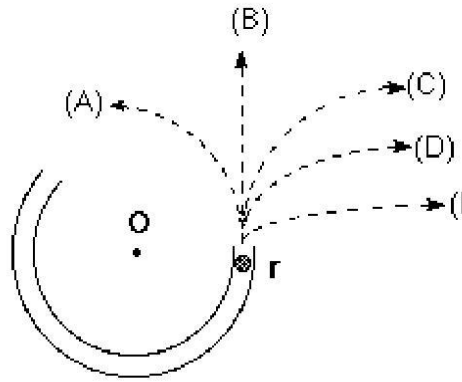
The accompanying figure shows a frictionless channel in the shape of a segment of a circle with center at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r."



5. Consider the following distinct forces:
    1. A downward force of gravity.
    2. A force exerted by the channel pointing from q to O.
    3. A force in the direction of motion.
    4. A force pointing from O to q.

   Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?

   (A) 1 only.
   (B) 1 and 2.
   (C) 1 and 3.
   (D) 1, 2, and 3.
   (E) 1, 3, and 4.

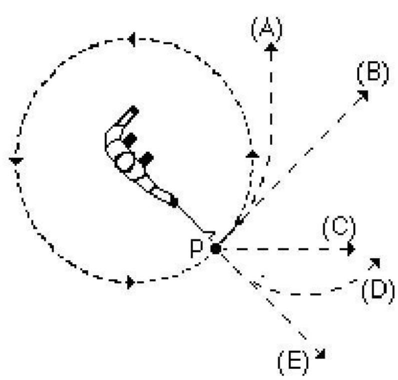


6. Which path in the figure at right would the ball most closely follow after it exits the channel at "r" and moves across the frictionless table top?

7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure.

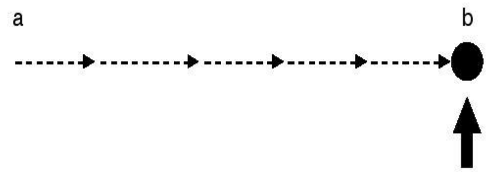
   At the point P indicated in the figure, the string suddenly breaks near the ball.

   If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?

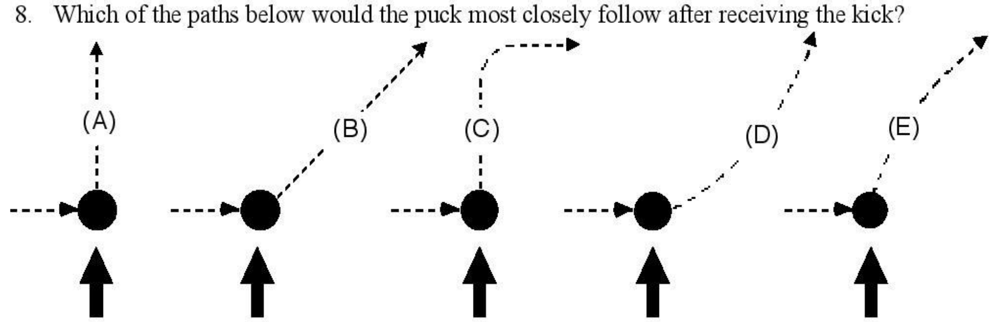


USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 through 11).

The figure depicts a hockey puck sliding with constant speed v_o in a straight line from point "a" to point "b" on a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down on the puck. When the puck reaches point "b," it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point "b," then the kick would have set the puck in horizontal motion with a speed v_k in the direction of the kick.



8. Which of the paths below would the puck most closely follow after receiving the kick?

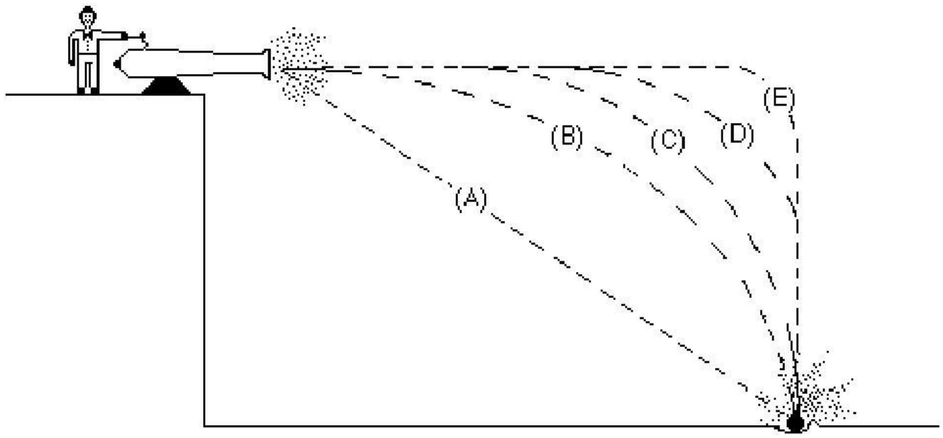


9. The speed of the puck just after it receives the kick is:
   (A) equal to the speed "v_o" it had before it received the kick.
   (B) equal to the speed "v_k" resulting from the kick and independent of the speed "v_o".
   (C) equal to the arithmetic sum of the speeds "v_o" and "v_k".
   (D) smaller than either of the speeds "v_o" or "v_k".
   (E) greater than either of the speeds "v_o" or "v_k", but less than the arithmetic sum of these two speeds.

10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick:
    (A) is constant.
    (B) continuously increases.
    (C) continuously decreases.
    (D) increases for a while and decreases thereafter.
    (E) is constant for a while and decreases thereafter.

11. Along the frictionless path you have chosen in question 8, the main force(s) acting on the puck after receiving the kick is (are):
    (A) a downward force of gravity.
    (B) a downward force of gravity, and a horizontal force in the direction of motion.
    (C) a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
    (D) a downward force of gravity and an upward force exerted by the surface.
    (E) none. (No forces act on the puck.)

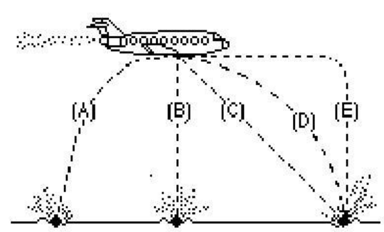
12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?



13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):
    (A) a downward force of gravity along with a steadily decreasing upward force.
    (B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.
    (C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.
    (D) an almost constant downward force of gravity only.
    (E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.

14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction.

    As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?



USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
    (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
    (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

17. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:

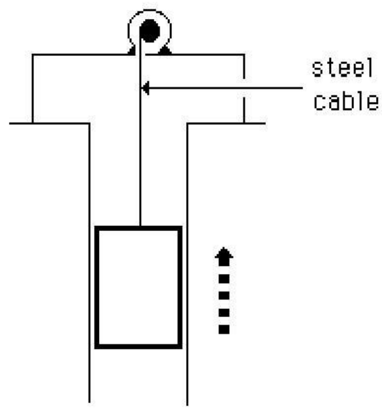
(A) the upward force by the cable is greater than the downward force of gravity.

(B) the upward force by the cable is equal to the downward force of gravity.

(C) the upward force by the cable is smaller than the downward force of gravity.

(D) the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.

(E) none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).



Elevator going up at constant speed

18. The figure below shows a boy swinging on a rope, starting at a point higher than A. Consider the following distinct forces:

1. A downward force of gravity.
2. A force exerted by the rope pointing from A to O.
3. A force in the direction of the boy's motion.
4. A force pointing from O to A.

Which of the above forces is (are) acting on the boy when he is at position A?

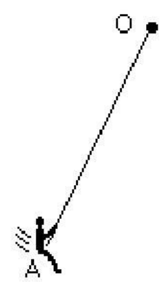
(A) 1 only.

(B) 1 and 2.

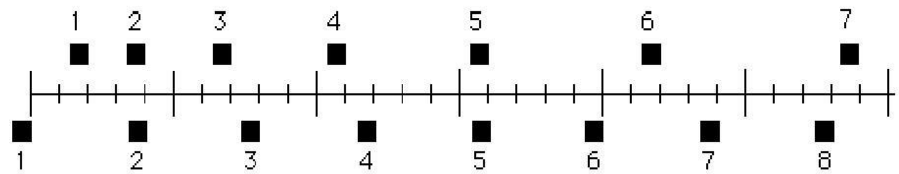
(C) 1 and 3.

(D) 1, 2, and 3.

(E) 1, 3, and 4.



19. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



Do the blocks ever have the same speed?

(A) No.

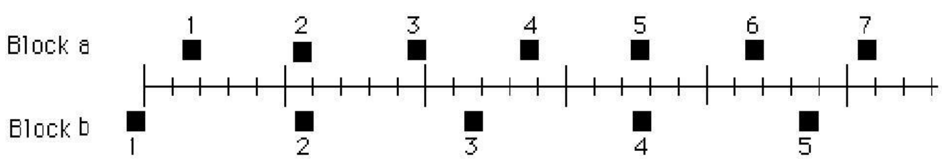
(B) Yes, at instant 2.

(C) Yes, at instant 5.

(D) Yes, at instants 2 and 5.

(E) Yes, at some time during the interval 3 to 4.

20. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



The accelerations of the blocks are related as follows:

(A) The acceleration of "a" is greater than the acceleration of " b".

(B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.

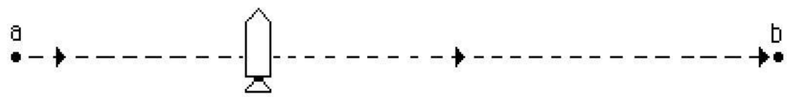
(C) The acceleration of "b" is greater than the acceleration of "a".

(D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.

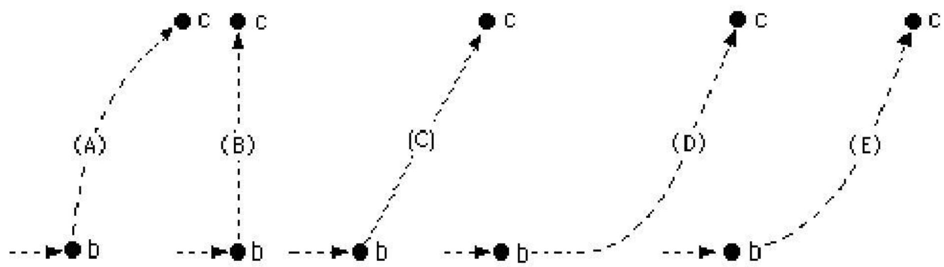
(E) Not enough information is given to answer the question.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (21 through 24).

A rocket drifts sideways in outer space from point "a" to point "b" as shown below. The rocket is subject to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to the line "ab". The constant thrust is maintained until the rocket reaches a point "c" in space.

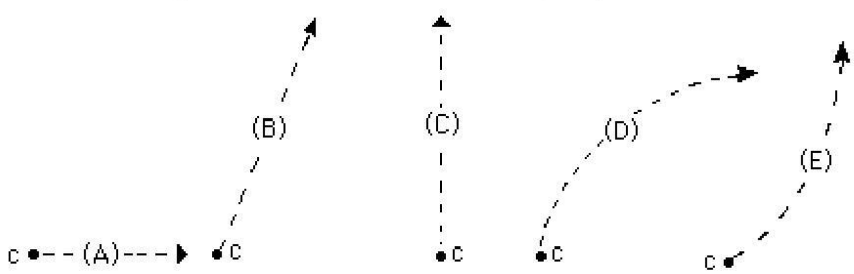


21. Which path below best represents the path of the rocket between points "b" and "c"?



22. As the rocket moves from position "b" to position "c", its speed is:
    (A) constant.
    (B) continuously increasing.
    (C) continuously decreasing.
    (D) increasing for a while and constant thereafter.
    (E) constant for a while and decreasing thereafter.

23. At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?



24. Beyond position "c" the speed of the rocket is:
    (A) constant.
    (B) continuously increasing.
    (C) continuously decreasing.
    (D) increasing for a while and constant thereafter.
    (E) constant for a while and decreasing thereafter.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed "v_0".

The constant horizontal force applied by the woman:

(A) has the same magnitude as the weight of the box.

(B) is greater than the weight of the box.

(C) has the same magnitude as the total force which resists the motion of the box.

(D) is greater than the total force which resists the motion of the box.

(E) is greater than either the weight of the box or the total force which resists its motion.

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:

(A) with a constant speed that is double the speed "v_0" in the previous question.

(B) with a constant speed that is greater than the speed "v_0" in the previous question, but not necessarily twice as great.

(C) for a while with a speed that is constant and greater than the speed "v_0" in the previous question, then with a speed that increases thereafter.

(D) for a while with an increasing speed, then with a constant speed thereafter.

(E) with a continuously increasing speed.

27. If the woman in question 25 suddenly stops applying a horizontal force to the box, then the box will:

(A) immediately come to a stop.

(B) continue moving at a constant speed for a while and then slow to a stop.

(C) immediately start slowing to a stop.

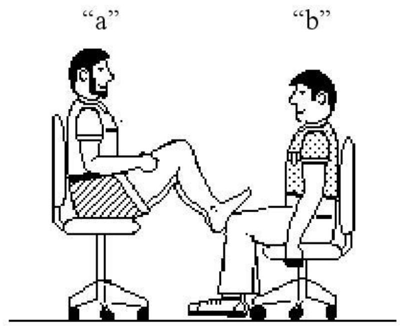
(D) continue at a constant speed.

(E) increase its speed for a while and then start slowing to a stop.

28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other.

Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.

During the push and while the students are still touching each other:



(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

29. An empty office chair is at rest on a floor. Consider the following forces:

1. A downward force of gravity.
2. An upward force exerted by the floor.
3. A net downward force exerted by the air.

Which of the forces is (are) acting on the office chair?

(A) 1 only.
(B) 1 and 2.
(C) 2 and 3.
(D) 1, 2, and 3.
(E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)

30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.

Consider the following forces:

1. A downward force of gravity.
2. A force by the "hit".
3. A force exerted by the air.

Which of the above forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?

(A) 1 only.
(B) 1 and 2.
(C) 1 and 3.
(D) 2 and 3.
(E) 1, 2, and 3.

Appendix F: MOODLE Lesson (*screenshot)*