FLIPPED CLASSROOM LEARNING IN HIGH SCHOOL PHYSICS

by

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ABSTRACT

This project examined the effects of a flipped classroom teaching method on the engagement and achievement of high school physics students. The students involved in the study had been enrolled in a physics class for the first half of the school that was taught using a traditional method. At the midpoint of the school year, the course transitioned to a flipped style in which students were required to watch video lectures for homework. With lecture material moved outside of the classroom, class time was devoted to practice problems and lab activities. The students' progress during the study was monitored through pre- and post-unit assessments. Data provided by the county on district quarterly assessments was used to compare students in the treatment group to their own past performance and the performance of students in previous school years. Students also completed an engagement survey and participated in interviews and written reflections. The project results indicated that students showed as increased level of engagement in certain areas. The results also indicated that students learned material through the flipped classroom as effectively as they had in a traditional classroom setting.

INTRODUCTION AND BACKGROUND

South River High School is a public high school in Edgewater, Maryland and is part of the Anne Arundel County Public School System. The school has a total enrollment of just over 2,000 students. The school is consistently ranked amongst the top schools in the state of Maryland and was also ranked in the top 1,000 schools in the country by Newsweek in 2013 (2013 America's Best High Schools). Students attending South River live in a wide range of settings including rural areas in southern Maryland, the urban state capital of Annapolis, and outer suburbs of Washington, D.C. Despite the diverse areas in the school's district, 82% of the student population is Caucasian. The other 18% of students are a variety of minority groups, but the school has a growing Hispanic population since the introduction of an ESOL program in 2014. Nine percent of students receive financial assistance through the free and reduced meal service, though others may qualify for these services and choose not to use them. Classes at South River are taught on an alternating block schedule, with each class meeting for 86 minutes every other day. The schedule also includes an hour-long lunch break called NEST. During this time, students are able to see teachers for extra assistance and to make up missed assignments.

One of the goals of South River High School is for students to become self-directed individuals who are engaged both in their learning and in their communities. In recent years, teachers throughout the school have noticed a general decrease in student engagement and motivation. There are an increasing number of students, including those in upper level classes, who prefer to simply be given algorithms for solving problems rather than taking an active role in learning how to approach and solve these problems. This changing student attitude has had a negative impact on assessment scores across many classes. I have found this to be particularly evident in my standard level physics classes, where students tend to have weaker problem solving skills and less confidence in their problem solving abilities than in honors and AP level classes.

I developed the plan for this action research project while observing the actions of my physics students over the past two years. During this time, I had primarily taken a traditional approach to delivering course material during class time and having students complete practice problems for homework. Labs were an important component in my physics classrooms, but only the data collection was traditionally completed during class time; all analysis and conclusion questions were assigned for homework. Over time I began to realize that many students were not completing the assigned practice problems and lab reports at home. After discussing this issue with several students, I began to learn that they had difficulty relating the material covered in class to the assigned homework. Some students were able to come see me during NEST for additional help, but many were not. As students became more discouraged by the challenging homework assignments, they became less motivated to attempt them at all. Without completing the homework practice, students were not well prepared for exam problems and began scoring poorly on tests and quizzes. As my students became more discouraged, I saw them heading into a downward spiral and a mindset in which they felt they could never be successful in physics class.

In an attempt to address this growing problem, I began spending additional class time going over the assigned homework problems. The change seemed to be beneficial to many students, but it also had some drawbacks. Spending additional time going over homework problems meant there was less time in class to complete laboratory investigations and cover the required course content. I became interested in the flipped classroom approach as a way to reallocate class time to be more beneficial for the students. In the flipped approach, students would be able to complete all of their practice problems in class with me as a resource when they became stuck. I felt that this would likely help students work through challenging problems rather than giving up and becoming discouraged. In turn, this could help them understand the material better and improve their test scores in physics.

The purpose of this study was to explore how using a flipped classroom approach would improve student learning and motivation in a physics classroom. My focus question was, how will implementing a flipped classroom affect student engagement and achievement?

CONCEPTUAL FRAMEWORK

Educational policies and standards are constantly evolving as researchers and educators learn more about the most effective ways to teach students. Science education in particular has changed significantly in recent years. Studies have shown the importance of student-centered learning and relevant experiences to student success in secondary science courses (Tomory & Watson, 2015). This has led to an increase in the use of inquiry-based learning and laboratory experiments in the science classroom. As educators are faced with new science standards, they have begun to investigate new ways to best meet the needs of their students. One of the methods that has become very popular in recent years is the flipped classroom (Project Tomorrow & Flipped Learning Network, 2015).

The idea behind the flipped classroom has been around for quite some time, but the increasing availability of technology and connected devices has allowed it to become a realistic method for more educators. In general, a flipped classroom approach takes the material that is traditionally delivered in class and now delivers this material as homework. Traditional homework assignments are then completed during class meeting time along with inquiry activities and labs. The Flipped Learning Network (FLN) further defined the flipped classroom by identifying the "four pillars of F-L-I-P" (Flipped Learning Network, 2014). The four pillars are flexible environment, learning culture, intentional content, and professional educator. These pillars indicate that it is not enough to simply move traditional content outside of the classroom. Rather, educators must change the environment of their classrooms to embody the flipped learning approach.

There are many reasons why the flipped classroom approach has become increasingly popular. One of the most important is the need to reallocate class time to meet the requirements of new science standards. The College Board has recently revised several of its Advanced Placement science courses to include more time for inquiry activities with the goal of giving students more authentic scientific experiences. While research has supported this change, educators have concerns about adding more inquiry into courses with already large curricula (Tomory & Watson, 2015). There is limited class time available to cover this additional material. Through the use of a flipped classroom, however, educators are able to create more time in class to complete lab activities that students would be unable to complete at home.

The flipped classroom approach has also been shown to provide more individualized learning for students. One of the key points behind the flipped classroom approach is for the learning to be student-driven with the teacher serving as a facilitator. When this shift occurs, the teacher is able to differentiate material for individual students. Bergmann and Sams (2012) were amongst the first to explore this idea in science education. In the traditional classroom approach, the instructor spends a large portion of class time delivering new material to students. The students are then sent home and expected to apply the material to a set of problems. This is often the time during which students need the most assistance. In a flipped classroom, students watch videos or screencasts of lecture material at home and then complete problem sets in class. Using this set-up, the instructor is available to students when they are most likely to need assistance. The instructor can address individual questions and concerns as they arise and help prevent any misconceptions from forming.

Abeysekera and Dawson (2014) have also explored the use of a flipped classroom to improve student motivation. In their work, they explained that self-determination theory identifies three basic cognitive needs – competence, autonomy, and relatedness – all of which can be met in a flipped classroom. Students in a flipped classroom are required to be active participants in their own learning, thereby facilitating needs for autonomy and competence. Flipped classrooms also involve more inquiry activities that help students experience a higher level of relatedness. They also argued that moving transmission teaching outside of the classroom helps students to better manage their cognitive load by allowing a more self-paced learning experience.

There have been some concerns regarding implementation of the flipped classroom, however. Access to technology was a common issue brought up by early researchers. All students need to have access to video lectures for the flipped classroom approach to be successful, but not all students have access to a computer or internet to watch these videos. Luckily, innovative educators have devised several ways to make the videos accessible to all students. Some teachers provided students with flash drives or DVDs of the lectures, while other districts were able to supply computers or tablets for students to check-out for the duration of the course (Bergmann & Sams, 2009). Another argument against the flipped classroom is that it further increases the amount of time students spend in front of screens, which is a common complaint about the younger generation (Bergmann & Sams, 2012; Ng, 2014). It could also be linked to potential health risks. Proponents of flipped classrooms addressed this concern by saying they are embracing the digital age rather than fighting it. In fact, this is one of the strongest arguments for the flipped classroom. The current generation's students have grown up in the digital age and are naturally digital learners. Bergmann and Sams (2012) argued that it simply makes sense to embrace the technology that students carry around in their pockets every day, and that this technology is often more advanced that what is available in underfunded schools. A study conducted by Project Tomorrow and the Flipped Learning Network (2014) showed that 40% of students already use online videos to help with homework or studying. These students were searching for and finding videos on their own, not as part of a flipped classroom experience. The results of the study further supported video as the means for delivering material to today's youth by surveying their social media habits. Only 4.5% of youths said they "never" go to YouTube, while 30% said they "never" use Instagram and 40% "never" use Facebook (Project Tomorrow & Flipped Learning Network, 2015). The survey proved that students today are accepting of and comfortable with online videos as a way to receive information. Students reactions to the flipped classroom supported this conclusion, as most students were not fazed by the use of videos in the classroom (Bergmann & Sams, 2012).

As the flipped classroom has become more popular in recent years, educators have begun implementing studies on the approach. The results of these preliminary studies have been quite promising. A study at the University of Massachusetts – Amherst compared student performance in an upper-level biochemistry course offered in both a flipped and traditional format (Gross, Pietri, Anderson, Moyano-Camihort, & Graham, 2015). The study found that students in the flipped format class performed nearly 12% better on exams than students in the traditional course format. They also found that students in the flipped class were more likely to complete online homework assignments over the course of the semester, rather than "cramming" right before the exam. Further analysis of the results indicated that the two groups of students who benefitted most from the flipped approach were students in the lowest overall GPA quartile and women. This indicated that the flipped classroom approach could be a useful tool in encouraging more women to enter STEM fields. A study at California State Polytechnic University showed that the use of online multi-media prelectures in an introductory physics course helped improve student performance (Sadaghiani, 2012). Students also had favorable reactions to the videos and indicated they were more likely to watch the video than complete prelecture reading assignments.

Many other studies have shown an improvement in student motivation and attitude towards learning in a flipped classroom environment. Tawfik and Lilly (2015) studied the use of video lectures in a college course on psychological statistics and received positive feedback on the videos from the majority of the study's participants. They cited several other studies in college-level statistics and science courses that had similar positive results. Dave Kawecki, a high school physics teacher in Wisconsin, used a flipped approach during his unit on magnetic fields. Student interviews indicated that the students liked having the ability to pause and rewind the videos. They also felt like they had more class time to spend on the material and that they learned the material better because of the video lectures. Kawecki found that his students performed equally as well on the unit test as students in previous years who had received the material through a more traditional delivery (Brunsell & Horejsi, 2013).

While the current research on the flipped classroom is very promising, the need for further research is quite apparent. Many educational researchers are calling for additional empirical studies in flipped classrooms (Abeysekera & Dawson, 2014; Ng, 2014; Tawfik & Lilly, 2015; Tomory & Watson, 2015). The majority of current research has been conducted on college campuses. There is a need for more research in high schools in order to determine if the same positive results will be seen at the secondary level as in higher education. Abeysekera and Dawson (2014) called for three specific types of investigations. In addition to the need for a larger scale meta-study, they called for additional small-scale localized studies and qualitative studies into student experiences in the flipped classroom.

The flipped classroom approach is one of the most interesting pedagogical techniques in current educational research. Researchers and educators alike are convinced of its effectiveness in meeting the needs of today's students. With increased focus on inquiry and individualized learning, the flipped method is quite appealing. Though current research has been quite promising, the need for further research in the high school setting is apparent.

METHODOLOGY

The purpose of this study was to investigate the effect of a flipped classroom on student achievement and engagement. The study was completed using four standard physics classes due to the large number of students enrolled in the course. Approximately ninety students from four different sections of the class were included in the study. As of the start of the study, these students had been enrolled in physics class for about five months. For these five months, the class was taught using a traditional teaching model with practice problems assigned for homework. The research methodology for this project received an exemption from Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Treatment

The study was conducted during the third marking period of the school year, which was approximately a two month span. During this time, students covered two separate units of study. The first was on conservation of energy and nuclear energy, while the second covered electrical circuits. For the duration of the study, all students were taught using a flipped classroom model. Videos covering new topics were to be watched for homework, while all practice problems and lab work were completed during class time. Some of the videos used were existing content available online while others were created based on previous years' in-class lecture material. Students were assigned to watch one or two video lectures before each class meeting. Since the classes are taught on an alternating block schedule, this gave students two nights to watch the assigned videos. The videos were delivered through an online platform called EDpuzzle. The students were instructed to take Cornell style notes while watching the video lectures. These notes were not checked in class, but students were able to use them on pop homework quizzes that were given throughout the treatment period. The videos also had integrated questions at critical points to check for students' understanding of the material. The EDpuzzle platform allowed me to track each student's progress, including whether or not they had watched the videos and how they scored on the integrated questions.

During the treatment period, all new material was being presented through the video lectures that the students watched at home. This freed up additional class time to focus on solving problems and completing lab activities. A typical class period would include an interactive problem solving activity, teacher lab demos, or a hands-on lab activity. The exact lesson plan was guided by student responses to the integrated video questions. At the beginning of each class there was time reserved for students to ask clarifying questions about the videos they had watched the night before.

Data Collection

Prior to beginning the study, each student took the Student Engagement Survey to measure their perceived level of engagement in physics class up to this point in the school year (Appendix B). This survey gave students a series of statements relating to their level of engagement in the classroom. Students had to select one of five options ranging from *strongly disagree* to *strongly agree*, each of which corresponded to a numerical value of one thru five. At the end of the treatment period, students took the Student Engagement Survey for a second time. The results from the surveys were compared and analyzed using a Wilcoxon Signed Rank Test.

At the beginning of each round of data collection, students took a pre-assessment on the topics to be covered during the course of the unit. For the first round of data collection, the pre-assessment was the Energy Transfers and Nuclear Energy Unit Assessment, which covered topics on conservation of energy, work, radioactive decay, and nuclear fission and fusion (Appendix C). The second round of data collection covered a unit on electric circuits, so students took the Electric Circuits Unit Assessment as their pre-assessment (Appendix D). The pre-assessment was necessary to identify a baseline score for students before they received any instruction, since students typically enter physics class with a wide range of academic backgrounds. At the end of each unit, students took the same assessment a second time. The results from the pre- and post-assessments were compared using a normalized gain calculation in order to determine how well students had learned the material over the course of the study. According to Hake (1998), average normalized gain scores of greater than 0.7 constituted high gain; scores of between 0.3 and 0.7 constituted medium gain; and score of less than 0.3 constituted low gain.

All students were required to take a quarterly assessment at the end of the third marking period. The quarterly assessment was written by the High School Science Office within Anne Arundel County Public Schools, and was administered to all students enrolled in standard physics throughout the county. Students had taken a similar assessment at the conclusion of the second marking period, just prior to the beginning of the study. Analysis of the county-reported quarterly assessment data was used to compare student achievement while learning under the flipped classroom environment to their achievement in a traditional classroom environment. Individual student scores from the second and third marking period quarterly assessments were analyzed using the Wilcoxon Signed Rank Test to look for any significant change in the median score on the two assessments. Additionally, the average scores on the third marking period quarterly assessment for South River High School and other reported schools were compared to the average scores on the same assessment given during the previous school year, when I taught the course using a traditional style classroom.

Finally, a small group of students participated in interviews before and after the study in order to supplement the information gathered from other data sources. The interview questions were designed to gain a better understanding of student perception of their own engagement and achievement (Appendix E). The same set of five questions was asked before and after the treatment period. During the post-treatment interviews, two additional questions relating specifically to the use of video homework were asked. Due to time constraints, interviews could only be conducted with a small number of students. However, all students completed a written reflection at the end of the treatment period. The responses to the student interviews and reflections were analyzed for themes and trends to support results gathered from the other data collection instruments.

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
1. How does a flipped classroom impact students' conceptual understanding in a physics class?	Pre and Post Unit Assessments	County-wide Quarterly Assessment results	Student Interviews and Reflections
2. How does a flipped classroom impact student engagement in a physics class?	Student Engagement Survey	Student Interviews and Reflections	

DATA AND ANALYSIS

The median score on the Energy Transfers and Nuclear Energy pre-test was 40% and the median score on the post-test was 80% (*N*=81). Prior to the treatment period, only the upper 25% of students scored above 50% on the assessment, and only seven students earned a passing score of 60% or higher. After the treatment period, only four students did not receive passing scores on the post-test, and 75% of students earned a score of at least 70% (Figure 1). All of the students who received scores of less than 50%

on the post assessment also received scores below that level on the pre-assessment. Every student improved their score from pre-test to post-test by at least 10 percentage points, and the average normalized gain from pre- to post-test was 0.615, a medium gain (Hake, 1998).

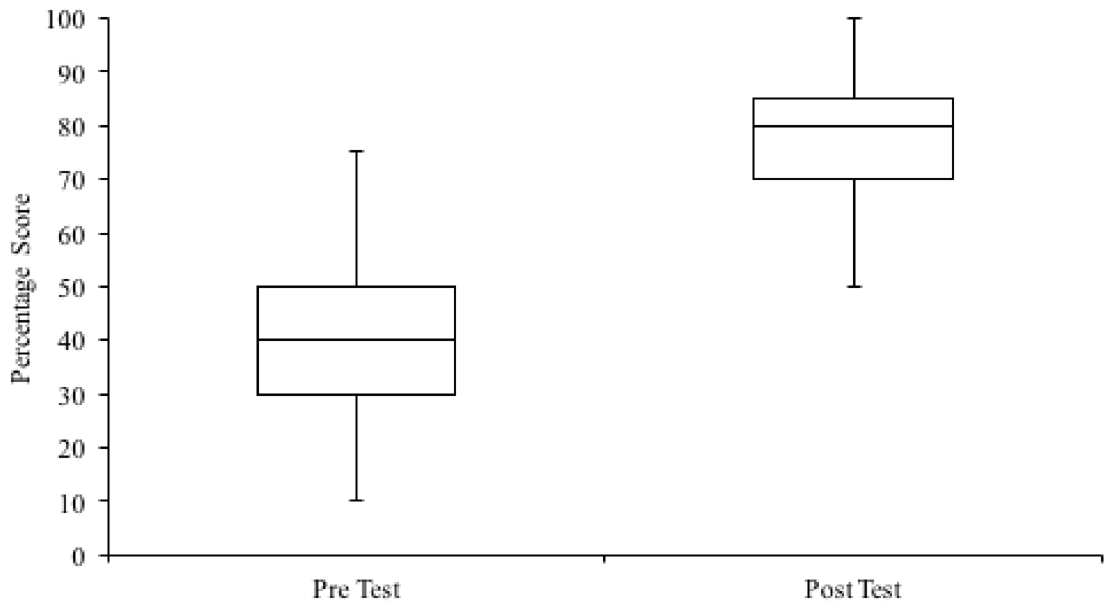

Figure 1. Comparison of pre-test and post-test scores on the Energy Transfers and Nuclear Energy Unit Assessment, (*N*=81).

The scores on the Electrical Circuits pre-test covered the same range as the Energy Transfers and Nuclear Energy pre-test, with a low score of 10% and a high score of 75%, but the median score on the Electrical Circuits pre-test was slightly lower at only 30% (*N*=85). The median on the Electrical Circuits post-test was also slightly lower at only 70%, but still showed an increase from the pre-test. The post-test scores on the Electrical Circuits assessment were far more scattered than for the Energy Transfers and Nuclear Energy post-test (Figure 2). While most students saw at least some improvement from their Electrical Circuits pre-test to post-test score, one student had no change between the two scores and another student actually received a lower score on the post-test than on the pre-test. Despite this, the average normalized gain from pre- to post-test was 0.552, a medium gain.

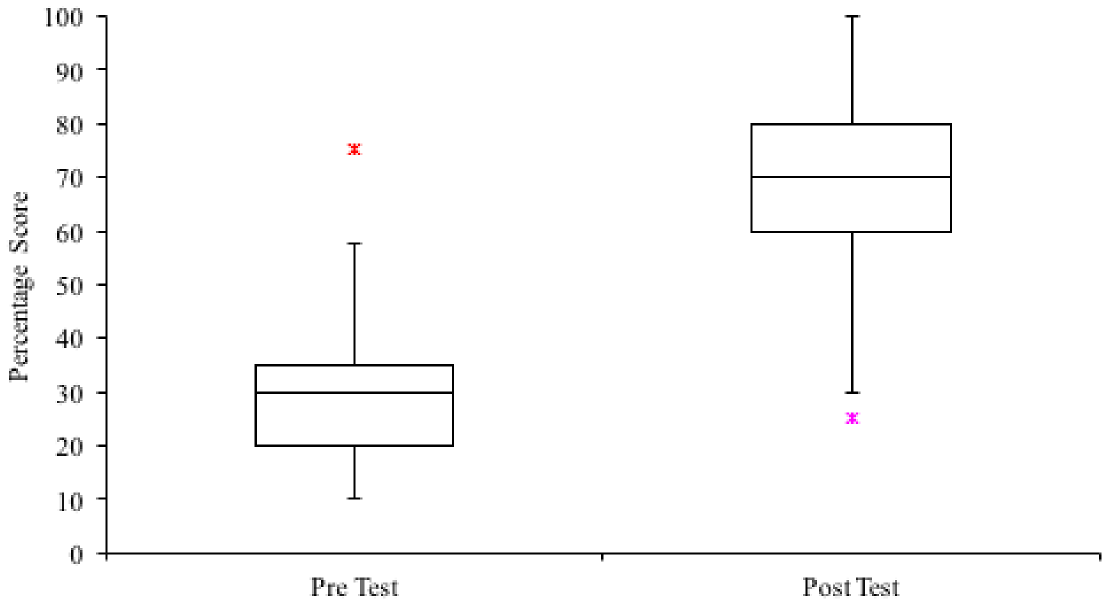

Figure 2. Comparison of pre-test and post-test scores on the Electrical Circuits Unit Assessment, (*N*=85).

Results of the Student Engagement Survey showed that students felt more prepared for tests and were more satisfied with their performance in physics class during the treatment period. When asked on the Student Engagement Survey if they felt satisfied with their performance in physics class, scores increased from 3.27 to 3.62 (*N*=71). This was a significant change as shown by the Wilcoxon Signed Rank Test, Z = 2.81, $p < 0.05$. Prior to the treatment period, 25% of students responded negatively to this question by selecting a response of either *disagree* or *strongly disagree*, and 45% responded positively by selecting a response of either *agree* or *strongly agree*. After the treatment period, only 15% of students responded negatively and 62% responded positively (Figure 3).

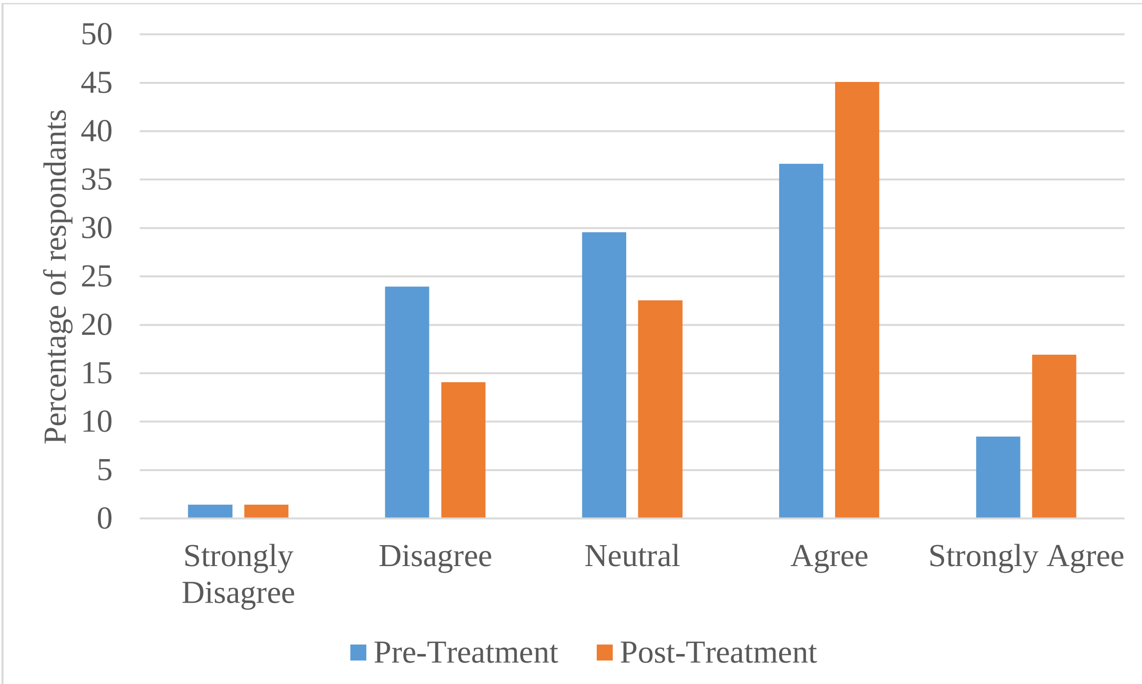

Figure 3. Pre- and post-treatment responses to question 9, *I am satisfied with my performance in physics class*, of the Student Engagement Survey, (*N*=71).

Scores on the Student Engagement Survey also increased from pre-treatment to post-treatment when students were asked whether they felt prepared for quizzes and tests in physics class (Figure 4). The average pre-treatment score was 3.24 and the average post-treatment score was 3.56. While initially only 45% of students responded positively to this question, the post-treatment survey showed 58% responded positively. The percentage of negative responses decreased from 20% to 11% on the post-treatment survey. In the interviews and reflection responses, several students indicated using the homework videos as a study tool. One student said, “I study for physics by reviewing the homework videos. I think they are extremely useful and a huge help.” Another student was hesitant about the video homework initially, but later found them valuable because they "made my note taking better, and are preparing me for what's to come next year at online college." While some students indicated clearly using the videos as an additional study tool, others appeared to maintain more traditional study methods. When asked how she studied for physics class during the pre-treatment interview, one student responded, "if we are given a review packet I try to solve it without my notes and then look at my notes and answer it that way." Her response to the same question during the post-treatment interviews was very similar, with no mention of the homework videos.

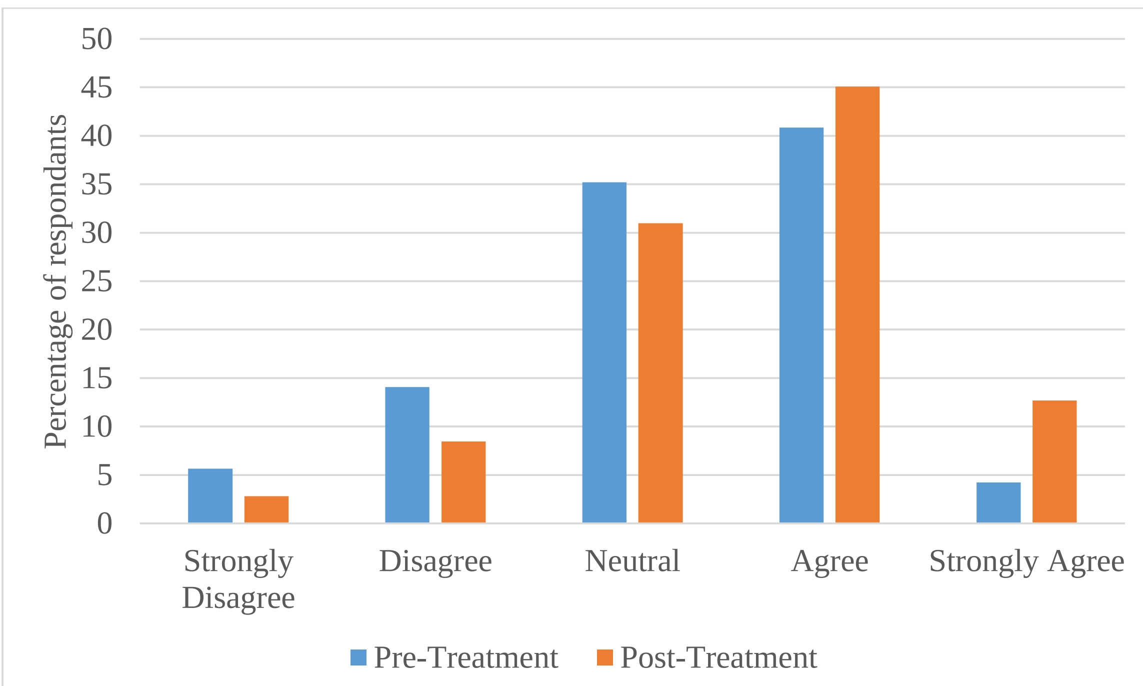

Figure 4. Pre- and post-treatment responses to question 4, *I feel prepared for quizzes and tests in physics class*, of the Student Engagement Survey, (*N*=71).

The mean score on the Anne Arundel County Public Schools Quarter 3 Assessment for students in the treatment group was 75.1% and the average score for these students on the AACPS Quarter 2 Assessment was 73.3% (*N*=81). The difference between the scores on the two assessments was shown to be not significantly significant by the Wilcoxon Signed Rank Test, showing students performed roughly the same on the material taught via the flipped classroom method as on the material taught through a traditional method. The quarterly assessment data was also compared to other schools in the county for both the 2017 and 2016 administrations (Table 2). The county-wide average on this assessment increased by 9.1% from the 2016 administration to the 2017 administration. The average score for students at South River High School improved from 65% in 2016 to 75.5% in 2017. This represents a 10.5% gain, which is roughly in line with what was seen county-wide. In the rankings among schools in the county, South River was fourth out of seven reporting schools in 2016 under a traditional teaching method and second out of eight reporting schools in 2017 under the flipped classroom method.

Table 2
County-Wide Third Quarter Assessment Results for 2016 and 2017 Administrations

Year:	2016		2017	
School:	Average Score	Rank	Average Score	Rank
Broadneck	70	1	75.8	1
South River	*65*	*4*	*75.5*	*2*
Severna Park	68	2	73.6	3
Chesapeake	66	3	69.6	4
Old Mill	50	7	67.8	5
Arundel	---	n/a	65.7	6
Northeast	54	6	56.4	7
Meade	---	n/a	51.7	8
Annapolis	55	5	---	n/a
Overall	62		71.1	

During the treatment period, students reported increased engagement in certain areas but not others according to the results of the Student Engagement Survey. A Wilcoxon Signed Rank Test indicated that students enjoyed the activities we did in physics class more during the treatment period (M=3.92) than prior to the treatment period (M=3.55), Z=2.94, p <0.05. The largest change of any of the questions on the Student Engagement Survey was when students were asked whether they enjoyed the activities we do in physics class (Figure 5). In the pre-treatment survey, only 54% of students responded positively and 44% responded neutral. In the post-treatment survey, 80% of students responded positively to this question and only 15% were neutral. In both pre- and post-treatment interviews, many students identified lab activities as their favorite part of physics class. One student remarked, “The labs are my favorite thing about physics. I don’t like sitting and doing problems, I like being active.”

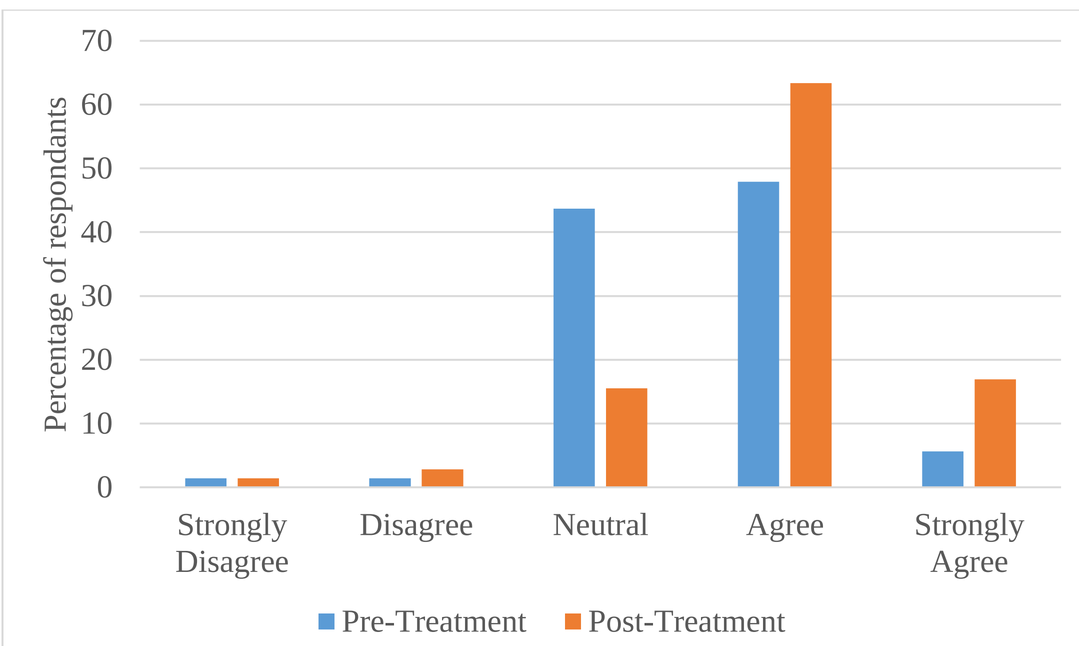

Figure 5. Pre- and post-treatment responses to question 3, *I find the activities we do in physics class to be interesting*, of the Student Engagement Survey, (N=71).

Students also showed modest improvement in their responses on the Student Engagement Survey when asked if they look forward to coming to physics class each day. Before the treatment period, 15% of students responded negatively to this question and 46% responded positively, while after the treatment period, only 6% responded negatively and 55% responded positively (*N*=71). The number of neutral responses remained relatively unchanged. In interviews and reflections, several students indicated that physics was their favorite class. While some students said it was because they enjoyed the content and learning something new each day, other students cited alternative reasons. One student indicated she enjoyed physics class because, "the content we learn is relatively easy…also I have several friends in the class." Finally, when asked outright about their level of engagement in physics class, students generally reported feeling more engaged in the post-treat survey than on the pre-treatment survey. The percentage of positive responses to this question increased by 11%, from 59% to 70%, between the two surveys, while the percentage of negative and neutral responses decreased by 4% and 8%, respectively.

Other areas of the Student Engagement Survey showed little to no change from pre-treatment to post-treatment. Analysis using the Wilcoxon Signed Rank Test showed that the pre- and post-treatment responses for two questions were not significantly different. These questions asked whether students came to class prepared with homework completed and whether they were working to the best of their ability in physics class. While students' responses to other questions indicated an increased level of engagement in class, their responses to these two questions indicated that their level of engagement in homework and other assignments had not necessarily changed. In interviews and reflections, students also reported mixed feelings towards the new style of homework. Many students were positive about the homework videos for a variety of reasons. When asked whether he thought the videos were helpful, one student responded, “Yes! The videos are a fun, interactive way to learn new subjects. I love the videos.” Another student liked the convenience of the videos and that he could, “go back and watch them any time – can’t lose them,” unlike paper notes that he easily misplaced. Other students were far less positive about the homework videos, reporting a variety of concerns. One student replied, “I don’t think the videos helped. If anything I lost focus watching them,” while another said, “I did not like the videos. I did not take notes, I always forgot to watch them, and I always ‘zoned out’ while watching them.”

Another area that showed mixed responses involved students asking and answering question. Questions five and six on the Student Engagement Survey asked about these two topics. Students’ responses showed no significant change when it came to asking questions in class, and only a minor improvement for answering questions. One student summarized his view on the issue in his reflection.

> Even though [the videos] save class time, you can’t really ask relevant question, making it hard to learn content on any new topics or ask any questions out of the point of curiosity. The comments section at the end [of the video] was not very useful for me as a lot of my questions were not something I wanted to have a delayed response on. After some time, I lost interest in the questions I once had.

While some students did utilize the comments section at the end of each video, many students still reported wishing they had more time to ask questions during class. Others said they simply did not feel comfortable asking questions in front of other students, but felt that there was sufficient time in class or during tutoring sessions to have their questions answered.

INTERPRETATION AND CONCLUSION

The purpose of this study was to determine the effect of flipped classroom instruction on both student achievement and engagement in physics. The results from the pre- and post-assessments for each of the data collection periods show that students did successfully learn the new material under flipped classroom instruction. Under this approach, the majority of students were able to reach an acceptable proficiency level in the material by the end of the unit.

I was also able to compare students' performance during the treatment period to their prior performance in units that were taught in using a traditional method, as well as to students from previous years who were taught this material using a traditional classroom. The students in the study received comparable scores on the third quarter county assessment as they did on the second quarter county assessment, for which the material was taught in a traditional method. Although the content taught in the two units is not directly comparable, the score distributions on the two standardized assessments were very similar, indicating that students learned equally well under the flipped approach and the traditional approach. When comparing the average score on the third marking period assessment to the same test given the previous year when students were taught with a traditional method, South River students' scores improved by roughly the same amount as the county-wide average. When looking at rankings among schools, South River moved up significantly. While this is not a completely direct comparison since some schools only reported scores one of the years and I also do not know if the teaching methods in those schools remained stagnant from 2016 to 2017, it is safe to say that South River students at least maintained a steady achievement level under the flipped classroom approach. More controlled studies would need to be done to see if the flipped method was in fact superior to other methods, but the results of this study indicate that it is a valid alternative to traditional methods.

The second goal of this study was to look at student engagement under the flipped classroom model. Most students appeared to enjoy the flipped approach and the use of homework videos, but some students responded very negatively towards them. This mixed result is not particularly unexpected, since all students learn best in different ways. The results of the Student Engagement Survey indicate that engagement increased modestly in most areas. Students reported feeling better prepared for tests and quizzes, being more satisfied with their performance in the class, and being more interested by the activities we did in class. This final point was particularly important because most students also reported that their favorite activities in class were the labs and other hands on activities. Since students were completing their notes outside of the classroom during the study we had more time to do labs during class. This ultimately allowed me to have students complete more hands-on activities that I would have if the unit were taught traditionally. Lab work is an important part of science classes, and one that many students enjoy, so this was an important benefit of the flipped classroom. The flipped classroom also allowed students to complete their lab analysis and conclusions during class time rather than at home, so they were able to receive more help and guidance if it was needed.

The students who were less positive towards the homework videos provided a lot of feedback that could be useful in addressing some of their concerns with the method. Major concerns included not remembering to watch the videos, not having the ability to ask questions while they were learning the material, and not always taking good quality notes while watching the videos. Knowing these are areas of concern, I can now adjust the way in which I implement the flipped classroom in the future. First, I will make sure there is dedicated time at the beginning of each class period to discuss any questions that arose from the previous night's homework video. During this time I will go over any questions that were sent electronically and also answer any additional questions the class has. During the study period I did this on occasion, but in the future I would make it more structured for the students. Additionally, I would hold dedicated review sessions each week to go over the material covered in the video. These sessions would give students who prefer a more traditional lecture setting a chance to receive new information in a way that works better with their learning style. These sessions would be offered during the school day's dedicated study hour or after school.

Finally, although engagement seemed to increase, the motivation level did not necessarily improve. Two of the areas in which students showed little change during the study involved whether they came to class prepared and whether they worked to the best of their ability in the class. The flipped classroom method alone, as implemented in this study, was not enough to change student motivation.

VALUE

Implementing a flipped classroom was something I had been interested in doing since I started teaching. There is a lot of current research on the topic, and much of it is very promising on the effects that flipped classrooms can have on student outcomes, especially in science classrooms. I had hesitated to try the approach because I was worried about the amount of work it would require and was unsure if the results would be worth it. After completing this research project, I now have first had experience with this alternative classroom approach. The amount of work it took to transition my lessons to this new format was much more manageable that I originally expected. Although some students did not like the new style, the majority of students had very positive things to say about it, which encouraged me to continue using the method beyond the intended treatment period. The amount of class time I saved by moving traditional lectures outside of the classroom was one of the greatest benefits in my opinion, and I could see this being very beneficial for AP-level courses that often have limited time to cover the entire curriculum. I also learned about several resources that are available and easy to use for teachers that want to begin transitioning to a flipped classroom.

From the students' point of view, I think experience a flipped classroom was also very valuable. Our current generation of students have grown up using a lot of technology, and we often assume they will be comfortable and competent on any new platform. After observing my own students, I have learned that this is not always the case. While some students were able to easily navigate the EDpuzzle platform, others needed significant help to get started and work through technical glitches along the way.

As many universities move to put more content in online platforms, I think it's important for high school teachers to expose students to this early on.

Moving forward, I would definitely like to keep developing the use of a flipped classroom. I chose only to implement the study with my standard level students, but I see it as potentially more valuable with my AP-level students who are typically on a tight time schedule. I also think there needs to be more information provided to teachers about the resources available for flipping. While many teachers utilize videos in class, few others in my department were aware of all the platforms that can be used to turn videos into at-home assignments. With a larger group of teachers implementing the flipped classroom, I think it would be easier to compare results between traditional methods and various flipped classrooms in order to identify methods that produce the best results for students.

Completing this study has had a significant impact on my teaching style and my understanding of how students learn. Science classes lend themselves naturally to student-centered learning, but I previously felt that I needed to use some amount of the valuable class time to present new material in a traditional lecture format. After the study, I now know that I can successfully move these traditional lectures out of the classroom without having a negative impact on my students. Prior to the study, I was a strong believer in the use of traditional homework problems as an important way for students to learn new material. Throughout the course of the study, I realized that students got far more value out of practice problems that were completed during class time, which would allow students to ask questions as they arose rather than the next time they saw me in class. Finally, while completing this study I realized the importance of adjusting instructional methods to meet the needs of all students. While some students thrived under the flipped classroom, others seemed to struggle more than I expected. The feedback I received from students highlighted some of the challenges they faced with this new learning style. I can now use this information to adjust my instruction and in-class activities in order to reach all of my students' needs. While not every aspect of the study went as I expected, completing this study opened my eyes to new instructional methods that can be as effective – if not more effective – than traditional classroom instruction.

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APPENDICES

APPENDIX A

IRB EXEPMTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Jill Cleveland and John Graves
FROM: Mark Quinn *Mark Quinn cj*
DATE: November 22, 2016
SUBJECT: "*The Effects of a Flipped Classroom on Student Engagement and Achievement in a High School Physics Classroom*" [JC112216-EX]

The above research, described in your submission of November 21, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement}, survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

STUDENT ENGAGEMENT SURVEY

STUDENT ENGAGEMENT SURVEY

Please answer the following questions by circling the response that best represents your opinion. Participation in this survey is voluntary and will have no impact on your grade in this class.

1. I look forward to coming to physics class each day.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

2. I come to physics class prepared and with my homework complete.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

3. I find the activities we do in physics class to be interesting.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

4. I feel prepared for quizzes and tests in physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

5. I feel comfortable **asking** questions during physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

6. I feel comfortable **answering** questions during physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

7. I feel engaged during physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

8. I work to the best of my ability in physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

9. I am satisfied with my performance in physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

10. It is important to me to do well in physics class.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

APPENDIX C

ENERGY TRANSFERS AND NUCLEAR ENERGY UNIT ASSESSMENT

Unit 5: Gone Fission

Useful Information:

Work: $W = F \times d = \Delta E$
Work against gravity: $W = mgh$
Hook's Law (springs): $F = kx$
Kinetic Energy: $KE = \frac{1}{2}mv^2$
Gravitational Potential Energy: $PE = mgh$
Elastic Potential Energy: $PE = \frac{1}{2}kx^2$
Speed of light = 3.0×10^8 m/s
Mass-Energy Equivalence: $E = mc^2$

Mass of a proton = 1.673×10^{-27} kg
Mass of a neutron = 1.675×10^{-27} kg
Mass of an electron = 9.109×10^{-31} kg
Alpha particle: ${}^{4}_{2}He$
Beta (minus) particle: ${}^{0}_{-1}e$
Positron: ${}^{0}_{+1}e$
Gamma ray: ${}^{0}_{0}\gamma$

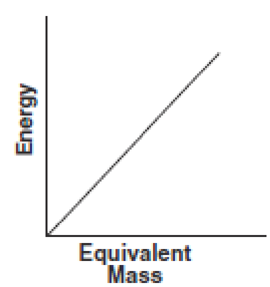
1. A student applies a horizontal force to move a crate at a constant speed across a rough floor. A second student then pushes the crate at the same speed with the same force but for only half the distance. How much more work did the second student do on the crate compared to the first?
   a. half as much
   b. the same amount
   c. twice as much
   d. four times as much

2. Which of the following best describes the atom

   I – Large-mass positive charges are found inside the nucleus
   II – Smaller-mass negative charges are found outside the nucleus
   III – Large-mass neutral charges are found outside the nucleus

   a. I & II
   b. I & III
   c. II & III
   d. I, II, & III

3. The graph represents the relationship between energy and the equivalent mass from which it can be converted. The slope of this graph represents
   a. c
   b. c^2
   c. g
   d. g^2



4. Higher temperatures are required for controlled nuclear fusion than nuclear fission because nuclei must overcome the forces of
   a. electrostatic attraction.
   b. electrostatic repulsion.
   c. magnetic attraction.
   d. magnetic repulsion.

5. A worker does 25 J of work lifting a bucket, then sets the bucket back down in the same place. What is the total net work done on the bucket?
   a. -25 J
   b. 0 J
   c. 25 J
   d. 50 J

6. Identify the particle that completes the following nuclear reaction:

$$^{3}_{1}H \rightarrow ^{3}_{2}He + ?$$

   a. proton ($^{1}_{1}p$)
   b. β⁻ particle ($^{0}_{-1}e$)
   c. α particle ($^{4}_{2}He$)
   d. positron ($^{0}_{+1}e$)

7. Which of the following statements describe a nuclear fusion reaction?
   I – A large nucleus splits into two smaller nuclei.
   II – Two small nuclei combine to form a larger nucleus.
   III – The mass of the system decreases and energy is released.
   IV – It occurs in the cores of stars, like the sun.
   a. I only
   b. I & III
   c. II & IV
   d. II, III, & IV

8. In a fusion reaction, reacting nuclei must collide. Collisions between two nuclei are difficult to achieve because the nuclei are
   a. both negatively charged and repel each other
   b. both positively charged and repel each other
   c. oppositely charged and attract each other
   d. oppositely charged and repel each other

9. What is the minimum total energy released when an electron and its antiparticle (positron) annihilate each other?
   a. 1.64×10^{-13} J
   b. 5.47×10^{-22} J
   c. 8.20×10^{-14} J
   d. 2.73×10^{-22} J

10. Which decay particle causes a change in mass number?
    a. Alpha particle
    b. Beta particle
    c. Positron
    d. Gamma ray

11. Most people consume approximately 2 kg of food per day. If the food were converted into energy with 100% efficiency, how many joules of energy would be produced?
    a. 6.0×10^{8} J
    b. 1.2×10^{9} J
    c. 1.8×10^{17} J
    d. 3.6×10^{17} J

12. A potassium-42 nucleus ($^{42}_{19}K$) releases a beta particle. What is the resulting daughter nucleus?
    a. $^{41}_{19}K$
    b. $^{43}_{19}K$
    c. $^{42}_{18}Ar$
    d. $^{42}_{20}Ca$

13. Which action would require no work to be done on the object?
    a. lifting the object from the floor to the ceiling
    b. pushing the object along a horizontal floor against a frictional force
    c. decreasing the speed of the object until it comes to rest
    d. holding the object stationary above the ground

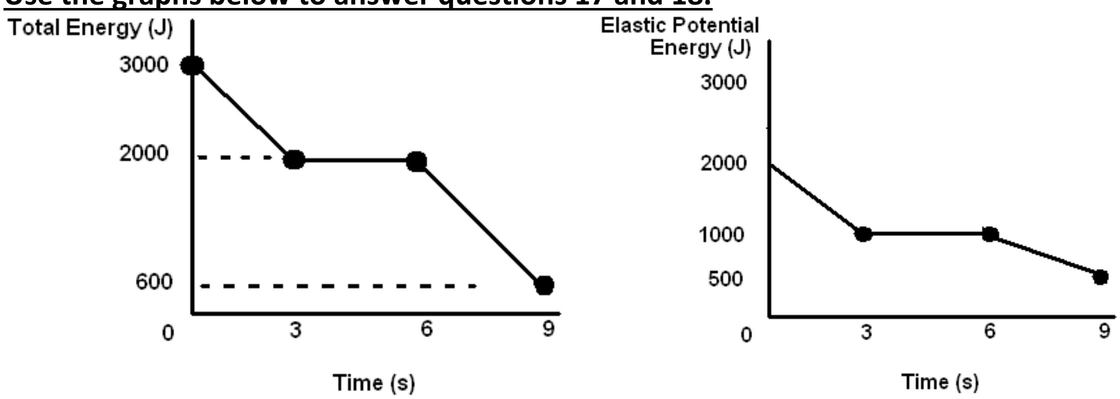
14. How much work is done on a downhill skier by an average braking force of 9.8×10^{2}N to stop her in a distance of 10m?
    a. 1.0×10^{1}J

b. 9.8×10^1J
c. 1.0×10^3J
d. 9.8×10^3J

15. A nucleus that is unstable will undergo radioactive decay. A nucleus will be unstable when the strong nuclear force is
    a. greater than the electrostatic repulsion force
    b. less than the electrostatic repulsion force
    c. greater than the electrostatic attraction force
    d. less than the electrostatic attraction force

16. Which pair of atoms are isotopes?
    a. $^{59}_{27}Co$ and $^{59}_{28}Ni$
    b. $^{1}_{1}H$ and $^{4}_{2}He$
    c. $^{12}_{6}C$ and $^{12}_{6}C$
    d. $^{35}_{17}Cl$ and $^{37}_{17}Cl$

Use the graphs below to answer questions 17 and 18.



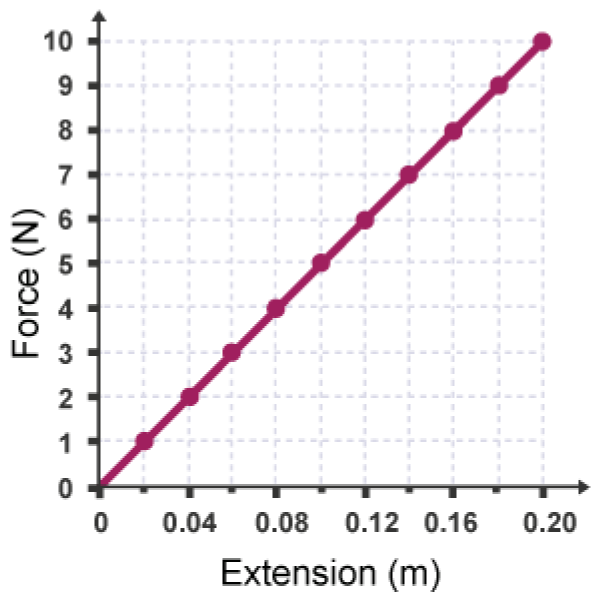
17. The graphs represent the total energy of a system as time continues. How much work is done on the system from 3-9 s?
    a. 0 J
    b. -1400 J
    c. -6300 J
    d. -8400 J

18. If the total energy is made up of just kinetic and elastic potential energy shown on the graphs, what is the kinetic energy of the system at 9 s?
    a. 100 J
    b. 500 J

c. 600 J
d. 1100 J

Use the information below to answer questions 19 and 20:

In a lab experiment, a student stretched a single spring to different lengths by applying various forces. The student recorded the data from the experiment, and the results are presented in the graph below.



19. Based on the data in the graph, the spring constant of the spring is approximately
    a. 5 N/m
    b. 10 N/m
    c. 50 N/m
    d. 100 N/m

20. How much elastic potential energy was stored in the spring when the student applied a force of 5 N to the spring?
    a. 0.25 J
    b. 0.5 J
    c. 2.5 J
    d. 5.0 J

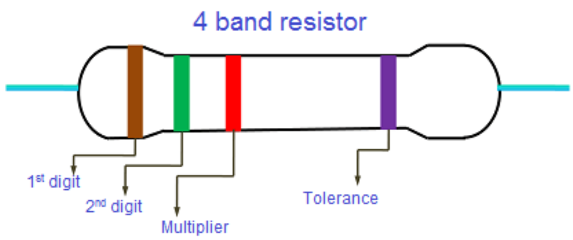
APPENDIX D

ELECTRICAL CIRCUITS UNIT ASSESSMENT

Circuits Quiz

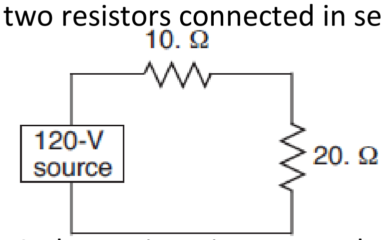
Useful Information:
Current: $I = {}^{Q}/_{t}$
Ohm's Law: $V = I \times R$
Resistance in a series circuit: $R_T = R_1 + R_2 + R_3 + \cdots$
Resistance in a parallel circuit: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20



1. If a 15 ohm resistor is connected in parallel with a 30 ohm resistor, the total resistance is:
   A. 15 ohms
   B. 2 ohms
   C. 10 ohms
   D. 45 ohms

2. The diagram below shows two resistors connected in series to a 120 volt battery.



If the current through the 10 ohm resistor is 4 amps, the current through the 20 ohm resistor is:
   A. 1 A
   C. 3 A

B. 2.0 A D. 4 A

3. A 3 ohm resistor and a 6 ohm resistor are connected in series in an operating electric circuit. If the current through the 3 ohm resistor is 4 amps, what is the voltage drop across the 6 ohm resistor?
A. 8 V B. 2 V C. 12 V D. 24 V

4. A circuit consists of a 10 ohm resistor, a 15 ohm resistor, and a 20 ohm resistor connected in parallel across a 9 volt battery. What is the total resistance of this circuit?
A. 0.200 ohms B. 4.62 ohms C. 1.95 ohms D. 45.0 ohms

5. When we call a circuit a "closed circuit" we mean:
A. the current is blocked and cannot flow
B. there is only one path for current to flow through
C. the pathway is complete with no gaps and current can flow
D. there is only one device connected to the power source

6. When two light bulbs are connected in parallel, which statement is true?
A. the total resistance is less than the resistance of either bulb alone
B. the voltage provided by the battery is split evenly between the two bulbs
C. if one bulb burns out, neither bulb will light
D. the current will be the same everywhere in the circuit

7. For a parallel circuit, which of the following statements is true?
A. the current through each branch is always the same
B. the voltage across each branch is the same
C. you must always have identical resistors in each branch
D. there is always a part that is wired in series

8. How many 6 ohm resistors would it take in parallel to make a total resistance of 3 ohms?
A. 6 B. 2 C. 3 D. 4

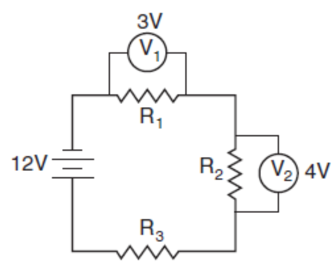
9. The current through two identical light bulbs connected in series is 0.25 A. The voltage across both bulbs is 110 V. The resistance of a single light bulb is

A. 22 ohms. B. 44 ohms C. 220 ohms D. 440 ohms

10. A 3 ohm resistor and a 6 ohm resistor are connected in parallel in an operating electric circuit. If the current through the 3 ohm resistor is 6 amps, what is the voltage drop across the 6 ohm resistor?
A. 12 V B. 18 V C. 24 V D. 36 V

11. A circuit consists of a 5 ohm resistor, a 10 ohm resistor, and a 20 ohm resistor connected in series across a 9 volt battery. What is the total resistance of this circuit?
A. 0.35 ohms B. 2.85 ohms C. 6.67 ohms D. 35.0 ohms

12. The diagram below shows a circuit with three resistors.



If the voltmeter V_1 reads 3V and the voltmeter V_2 reads 4V, determine the voltage drop across R_3.
A. 12 V B. 5 V C. 0 V D. 4 V

13. To increase the brightness of a desk lamp, a student replaces a 50-watt incandescent lightbulb with a 100-watt incandescent lightbulb. Compared to the 50-watt lightbulb, the 100-watt lightbulb has
A. less resistance and draws more current
B. less resistance and draws less current
C. more resistance and draws more current
D. more resistance and draws less current

14. The current through two identical light bulbs connected in series is 0.25 A. The voltage drop across the first bulb is 120 V. The total resistance of the circuit is
A. 30 ohms B. 60 ohms C. 480 ohms D. 960 ohms

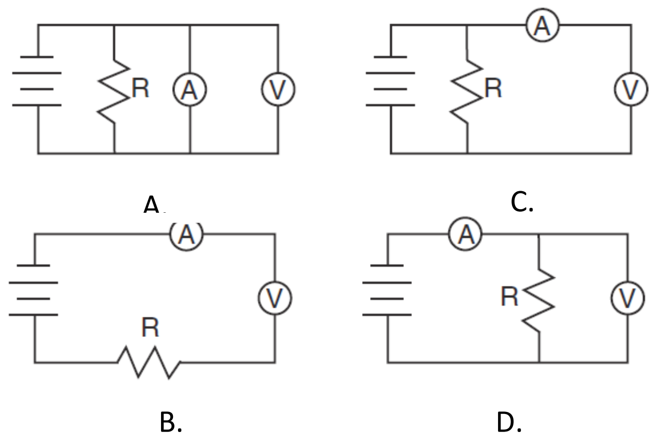
15. Three coulombs of charge pass through a wire in a quarter of a second. What is the current through the wire?

A. 1/12 A B. 3/4 A C. 4 A D. 12 A

16. What is the resistance of a resistor with the color code brown-green-black-silver?

A. 6 ohms B. 15 ohms C. 60 ohms D. 150 ohms

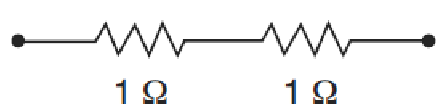
17. Which circuit diagram below correctly shows the connection of ammeter *A* and voltmeter *V* to measure the current through and potential difference across resistor *R*?



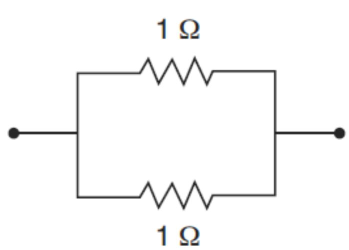
18. Which combination of resistors has the largest equivalent resistance?

A.

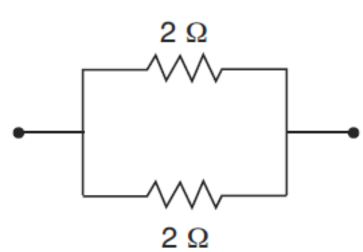
C.



B.



D.



19. Three lamps were connected in a circuit with a battery of constant voltage. The current, voltage, and resistance for each lamp are listed in the data table below.

	Current (A)	Potential Difference (V)	Resistance (Ω)
Lamp 1	0.34	20.3	59
Lamp 2	0.27	20.3	75
Lamp 3	0.18	20.3	112

Which of the following statements about this circuit is correct?

A. The bulbs are connected in parallel because the potential difference across each one is the same.
B. The bulbs are connected in parallel because the current through each one is the same.
C. The bulbs are connected in series because the potential difference across each one is the same.
D. The bulbs are connected in series because the current through each one is the same.

20. An electric iron operating at 120 volts draws 10 amperes of current. How much heat energy is delivered by the iron in 30 seconds?

A. 3.0×10^2 J
B. 1.2×10^3 J
C. 4.0×10^3 J
D. 3.6×10^4 J

APPENDIX E

STUDENT INTERVIEW QUESTIONS

Pre-Treatment

1. What are your favorite things about physics class?
2. What are your least favorite things about physics class?
3. What elements of physics class do you think help you learn best? (Notes, labs, practice problems, etc.)
4. Do you ask questions during class? Do you feel you have enough time during class to ask questions and get help from the teacher? Explain.
5. Describe how you study for physics when you are at home. What resources to you use to help you study?

Post-Treatment

1. What are your favorite things about physics class?
2. What are your least favorite things about physics class?
3. What elements of physics class do you think help you learn best? (Notes, labs, practice problems, etc.)
4. Do you ask questions during class? Do you feel you have enough time during class to ask questions and get help from the teacher?
5. Describe how you study for physics when you are at home. What resources to you use to help you study?
6. How did you feel about having videos to watch at home? Did you watch the videos regularly? Did you take notes while watching?
7. Do you think having the videos helped you learn physics better? Explain.