The Impact of Homework on the Achievement of Students with Varying Science Aptitudes in High School Physics

Matthew Deets

This research is a product of the graduate program in Natural Sciences at Eastern Illinois University. Find out more about the program.

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The Impact of Homework on the Achievement of Students with Varying Science Aptitudes in High School Physics

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BY
Matthew Deets

THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Masters of Science in Natural Sciences
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I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF THE GRADUATE DEGREE CITED ABOVE

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Abstract

When students in a high school physics class are separated into high, middle, and low aptitude levels, it was discovered that they do not all show the same benefits from completing homework assignments. The focus of this study was to analyze the relationship between the amount of homework that students complete and their performance on quizzes and exams. The results indicate that middle and high aptitude students benefit from completing greater amounts of homework, however, low aptitude students show no improvement by completing a greater number of problems.
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Introduction

In our modern society, students are becoming increasingly involved with extracurricular activities that extend beyond the school day. These extracurricular activities often involve athletics, music, religious groups, as well as maintaining a part time job. These activities are added to an already strenuous 7 – 8 hour school day where the students are engaged in learning activities. Research by Galloway et. al that was completed on 4,317 high performing students showed that students have difficulty balancing their personal lives, extracurricular activities, and homework (Galloway, 2013). By assigning large amounts of homework that may not have any specific goal besides additional practice, teachers are hindering the development of their students in other areas where the students may also be finding success. Students surveyed by Galloway explained that they viewed homework as “pointless” or “mindless,” however they completed the tasks simply to keep their grades up (Galloway, 2013). Stanford researcher Denise Hope states, “this kind of busy work, by its very nature, discourages learning and instead promotes doing homework simply to get points” (Parker, 2014). Homework should be a strategy used to challenge students and should force them to think critically about the task they are trying to master. Homework should not be used strictly for practice, but should be assigned with a specific purpose. Unfortunately, these assumptions are not always adhered to with the type of homework assignments given to our students today. Many students report that they are often able to complete assignments without having to think critically about the material and that they are just completing the assignment to maintain a good grade in class (Cushman). This
mentality towards homework does not lead to an increased understanding of the material. Instead, if the amount of homework is too substantial students could be put under too large of a cognitive load, which may actually decrease their performance in the classroom. A large cognitive load involves students being introduced to too much material in a short amount of time not giving their minds enough time to thoroughly process the information. Students should be focused on deliberate practice where they focus all of their energy on the concepts that they find most difficult and are able to pass over concepts that they have already mastered.

In this study we will consider the impact of allowing the students to focus their time on areas where they are struggling without the added fear of receiving a poor grade on homework assignments. By employing a more flexible homework technique where students complete optional homework assignments and daily homework quizzes covering problems from those homework assignments, students may focus on areas that give them trouble and skip the assignments that cover material of which they already have a complete understanding. By giving homework quizzes based on problems from the assignments and allowing students to use their homework as a resource when completing the quiz, students can complete only the problems with which they struggle before coming to class. This gives students the extrinsic motivation they need to complete the homework and allows them to be deliberate about their study habits, while allowing them the option of not completing the entire assignment if they feel confident they have already mastered
the concepts. The mastery approach gives students an increased ownership of their own learning and assists them in gaining the ability to identify concepts that they are struggling with and concepts where they have a solid understanding. The goal of this study is to look for correlations between how much homework students complete and their performance on assessments. Due to the fact that students come into the class with differing levels of knowledge base and other preparations we must take these factors into account, thus, students' overall aptitude toward science is taken into consideration to analyze the relationship between how much homework is completed and their overall assessment scores when separating the student population between high and low aptitude.

**Literature Review**

Providing students with homework to increase their educational achievement is a strategy that has been used throughout our educational history; however it has also been one of the most debated strategies as well. Throughout the late 1800s until the launch of Sputnik in 1957, there was a strong anti-homework mentality in the United States (Eren, 2011). Critics of giving large amounts of homework began to argue that it was taking away from music lessons, family time, and play without having any benefit to the students' academic achievement (Gill, 2014). With the launch of Sputnik there was a belief that the education system in the United States was falling behind the Soviet Union. Thus, since the 1960s there has been a drastic increase in the amount of homework students receive on a daily basis (Eren, 2011). It was a common belief among the country that the reason the USSR launched the
first satellite is because their students were working harder both inside and outside of the classroom. This led to an increase in homework as education became an "instrument of national defense" for the United States (Gill, 2004, pg 177). By 1980, the average high school student spent approximately thirty minutes on math and science homework each night (Maltese, 2012). In 2002, that number increased to one hour in each subject (Maltese, 2012). There has been much debate on whether this increase in homework has resulted in an increase in student achievement, or if it has simply increased our students' workload.

A study completed by Frederick Kontur and Nathan Terry at the United States Air Force Academy (USAFA) tested students' motivation to complete homework assignments when they were not given credit for completing homework as a part of the overall course grade. They found that only forty five percent of their students completed homework assignments when no credit was awarded (Kontur, 2014). Many students believe that homework is not worth doing if they will not receive credit for completing it. Students, especially at the high school level, only have extrinsic motivation to complete assignments, which includes getting good grades, maintaining a high GPA, and graduating (Scharff, 2010). If no points are given on assignments this motivation is taken away because students do not see the point in putting forth extra effort if they will not be awarded for it. Many students do not make the connection between homework practice and exam performance. There is very little intrinsic motivation in adolescents, which is based on interests and a desire to learn new things (Scharff, 2010). What Knotur and Terry found when they
increased the value of their homework to 10 percent of the overall course grade; they were able to tap into the students' extrinsic motivation and increased the average amount of homework completed to 80 percent (Kontur, 2014). It is extrapolated by a line of best fit that by increasing the overall percentage of homework to 15 percent that the percentage of homework completed by the students could be increased to 100 percent (Kontur, 2014). This is theoretical because it is unlikely to get 100 percent completion on assignments by students, but according to the graph we could be close to 100 percent if homework were made to be 15 percent of the overall course grade.

![HW Completion in Both Courses](image)

FIG. 1. Graph of homework completion percentage plotted against the amount of credit the students receive for homework in their overall grade (Kontur, 2014, pg 295).

A second technique that Kontur and Terry performed to try to increase the students' motivation to complete homework was giving students homework quizzes based off of the homework assignments, while once again making homework worth zero percent of the overall course grade. During the course of the first semester 8-10 homework quizzes were given with problems based on the homework assignments.
The only thing different about the problems is that numbers were changed, but the wording remained the same. The students were also allowed to use their homework assignments as a resource when completing the quizzes. The second semester the homework quizzes were not directly from the homework assignments, but were conceptually similar. When comparing the two semesters, Kontur and Terry found that homework completion for the first semester was on average 53 percent and second semester was an average of 38 percent (Kontur, 2014). This was a significant increase and students found more incentive to complete the assignments when it would directly and obviously assist them in completing homework quizzes.

Kontur and Terry also wanted to get insight on the value that students put on the homework assignments and how that impacted how much homework the students were willing to complete. The following questions were given to the students by an anonymous survey: 1) Completing homework problems helps me understand the physics concepts, and 2) I tend to perform better on exams when I do all of the homework problems (Kontur, 2014, pg 296). The students responded to the questions on a four-point scale: 4 – strongly agree, 3 – agree, 2 – disagree, 1 – strongly disagree (Kontur, 2014, pg 296). The surveys were averaged from each class and according to the results the more value the students put on the homework assignments, the more homework they were willing to complete. Students are willing to complete assignments as long as they believe that it is assisting them in understanding the material. Once again, even though students that completed a
greater amount of homework saw more value in doing so, was this helping to increase their overall performance in the class?

![HW Completion VS Perceived Value for Fall 2011](image)

![HW Completion VS Perceived Value for Spring 2012](image)

FIG. 2. Demonstrates the percentage of homework students complete based on their perceived value of homework assignments (Kontur, 2014, pg 297).

A common and often correct assumption that is made by most people is that the more you practice a specific skill, the better you will become. This is a fact that is easily noticed in athletics. If a baseball player wants to get better at hitting a curve ball, they spend hours practicing hitting curve balls. However, more practice is not always going to lead to an increase in skill level. For example, if the athlete decided
they need to improve their skills at hitting curve balls and all they practice hitting is fast balls when they are already proficient at hitting fast balls, this practice is not going to assist them in becoming a better batter. Instead their focus needs to be directed toward the areas where they need improvement and practicing the correct technique. Ericsson focuses on the concept of "deliberate practice". The idea behind deliberate practice is that individuals are completely focused on a specific skill for a limited amount of time. People cannot focus on one task for long periods of time; instead, daily practice should be completed for limited amounts of time each day in order to master a skill (Ericsson, 1993). If individuals practice for too much time on a daily basis this will lead to exhaustion and may begin to reduce the gains earned from the practice they completed (Ericsson, 1993). Exhaustion is something commonly seen in high school students. Many of them receive a limited amount of sleep each night from being over worked, which causes exhaustion during the school day. This can lead to a reduction in focus and will diminish the possible gains from completing assignments for practice. Ericsson states, "I would argue that students do not always care about improving, because they have so much work to do their only focus is on getting homework done as fast as possible, instead of focusing on mastering the task," (Ericsson, 1993, pg 365). Ericsson explains that the most effective amount of deliberate practice is approximately an hour per day (Ericsson, 1993). The following study completed by Maltese et. al. reinforces Ericsson's findings.
A study completed by Maltese et. al. using the National Education Longitudinal Study (NELS) demonstrates that students who complete 30-61 minutes of homework each night scored 1.8-2.2 points higher on standardized exams, and students that completed 61 – 120 minutes of homework each day has been shown to increase standardized test scores by 2.9 – 3.0 points over students that complete zero homework. However, any amount of time over 120 minutes and the scores begin to decrease once again. This study was completed on approximately 25,000 students from 1990 to 2002 (Maltese, 2012). The result from this study come from using the students standardized exam scores and their final course grades in the science class that they were taking at the time of the study. The students were also given surveys to record how much homework they completed in science each week during the study (Maltese, 2012). There are some assumptions that are made when it comes to the purpose of homework in this study. First, homework is seen as a way to extend the school day and provide opportunities for students to practice concepts and prepare for future material. It is also assumed that the homework being assigned is based on the learning goals of the class and is not simply for repetition. Secondly, students are on task and focused while completing homework assignments. Lastly, we assume that students have a correct understanding of the material before completing the assignments otherwise negative affects can take place leading to an increased misunderstanding of the material. If students misunderstand the material it is often difficult to rid them of this misconception (Maltese, 2012). One argument made against this study is that higher achieving students typically take the more advanced classes where more homework is given.
Thus, it is more likely that these students will produce higher standardized exam scores and better final grades in classes because they are higher achieving students. Lower achieving students typically take lower level classes where less homework is given and they most likely receive lower scores on standardized testing and final grades. These factors are not taken into consideration in this study.

A study completed by Kontur et al. demonstrates a different outcome than the previous study completed by Maltese and analyzes students that are all taking the same course. Kontur did not just study the effects on the amount of homework students completed on their overall grade. Instead, he broke approximately 1000 students down into four separate groups to study the impact of vary amounts of homework on high, medium high, medium low, and low aptitude science students in an electricity and magnetism course at the United States Air Force Academy (USAFA) (Kontur, 2015). All students at the USAFA are required to complete two semesters of calculus-based physics: mechanics, and electricity and magnetism (E&M). The students were separated into their varying aptitude levels based on the following criteria: their ACT math and science scores, their score on the Force Concept Inventory (FCI), their overall grade in calculus 1 and 2, and their overall score in the mechanics physics course which was taken previously to E&M (Kontur, 2015). The homework that was completed during this study was online homework from Mastering Physics and was a compilation of both conceptual based questions and problems. Students were given five attempts at each question and the homework was graded for the purpose of the graphs by completion. The graphs
below demonstrate the correlation between the percent of homework completed and the students' average exam scores during the term. The average exam scores are composed of two mid-term exams and a final exam. Each exam is composed of approximately 30-35 conceptual based multiple-choice questions and two or three homework based problems (Kontur, 2015). This data was taken for five semesters of electricity and magnetism classes. After analyzing the graphs Kontur et al. determined that high aptitude students benefitted from completing a greater amount of homework. The slope of the best-fit line indicates that for high aptitude students on average the more homework that is completed, the higher students scored on exams. However, a negative correlation was found for the low aptitude students. It appeared that the more homework that the low aptitude students completed the lower the students scored on the exam. The following graphs and tables show the data that was collected during the course of the study.
FIG. 3. Demonstrates the correlation between the percent of homework completed by each student and their average exam score (Kontur, 2015, pg 8).
Table 1. Shows the p-values for the slopes of the lines for all five semesters of study. The graphs that this data was taken from are similar to the graphs shown in the previous figure (Kontur, 2015, pg 9).

The table above shows p-values for the slopes of the graphs that compare the amount of homework completed by each student and their average exam scores. From this data Kontur concluded that three out of five semesters demonstrated a significant increase in exam scores after completing a greater amount of homework for high aptitude students. However, for low aptitude students, four out of five semesters demonstrated a significant negative correlation between the amount of homework they completed and their average exam score. The figure with the graphs labeled (a) and (b) above demonstrates that this data is accurate for both the conceptual and problem sections of the exams.
Kontur et al. hypothesized several different reasons for the variability in between his high and low aptitude students from the study. Low aptitude students may have had misconceptions going into the homework assignments. While completing the assignments some of these misconceptions may not have gotten caught and only compounded their confusion. Also, if these students were struggling to complete the assignments they may have also simply copied the assignments from their peers, which would not help them with their understanding (Kontur, 2015). Also, low aptitude students may have had difficulty separating magnetism concepts from electricity concepts when completing the exams resulting in lower test scores. On the contrary, high aptitude students use homework as a learning tool for new concepts while at the same time mastering old concepts from previous material. This allows high aptitude students to build their understanding from one concept to the next and continue to increase their exam scores.

The studies previously listed have been completed using more traditional methods of giving homework. Homework in the previous methods was simply given for practice with the belief that the more homework completed the more success students will have in classes. Ericsson states that "repetition alone is not enough, adequate feedback must be given to keep individuals using correct techniques and not gaining bad habits," (Ericsson, 1993, pg 367). Students must focus on deliberate practice for limited amounts of time each day to master a skill. Ericsson also explains that, "there is no reason to have students continue deliberate practice with a specific skill if they have mastered it," (Ericsson, 1993, pg 371). Bao et. al.
discusses what he calls a “flexible homework method” to allow students to focus their deliberate practice time on areas where they need improvement, not on areas they have previously been mastered (Bao, 2008).

Bao and his colleagues compared a traditional style of homework to teaching with a more flexible homework method. The traditional style of homework entailed giving approximately 10 problems per week and the professor grading all of the homework (Bao, 2008). The traditional style is difficult for the teacher, because if the teacher were to have 60 students in class then this means that they would have to grade 600 problems. This takes a considerable amount of time and if the teacher were to give constructive feedback on every missed problem the students would not get the assignments back for at least a few days. The other method of grading would be only grading a couple of the problems on each assignment, so once again, not enough feedback is given to the student. Bao quotes one of his students when they discussed homework on a survey given to the class, “I had no idea how to do it (homework), and when I get it back, I would still not have any idea how to do it,” (Bao, 2008, pg 878).

Bao compared this method with a more flexible method at Ohio State University in a calculus based physics class with 85 students. In the flexible method the students are given 30 homework questions on a weekly basis and they must complete 10 out of the 30 questions to turn in. Each question in the assignment was labeled with an (A), (B), or (C) to indicate to the student the level of difficulty of the problem, with
being the most difficult. The professors discussed with the students that if they were able to work out the (A) problems on their own that they would likely receive a high grade in the class and would do well on the exams (Bao, 2008). The solutions to the entire assignment were given to the students three to four days prior to the assignment being turned in so they could use the solutions as a guide. However, the students had to show their own work and method of completing the problems and were encouraged not to simply copy the solutions. The students were also told by their professors that 30-40 percent of the exam questions would come directly from the homework. The professors found that students were often completing more than the minimum 10 problems to help them prepare for the exams.

<table>
<thead>
<tr>
<th>Design feature</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solutions given in advance.</td>
<td>Provide timely feedback and support to students so that they might engage in effective problem solving practice.</td>
</tr>
<tr>
<td>More questions than requested.</td>
<td>Allow students to make choices that personalize and hopefully optimize their learning.</td>
</tr>
<tr>
<td>Rating of difficulties</td>
<td>Allow students to monitor their own progress.</td>
</tr>
</tbody>
</table>

FIG. 5. The features of the flexible homework method and their corresponding goals (Bao, 2008, pg 879).

The results from the experiment showed that 75 percent of the students preferred the flexible method of completing homework assignments over the more traditional method. The study also demonstrated that over 70 percent of the students did not
copy the solutions to the assignments but used their own methods to solve the problems. This data was reported from the students' observations of the homework that was turned in. Students reported that they were happier, more relaxed, and more motivated to complete the assignments. Students reported that they were completing the assignments to learn the material instead of just trying to get them done by the due date (Bao, 2008). The flexible homework method also led to a 5-7 percent increase on the mechanics baseline exam over the traditional method. This was after no significant difference in the students' background scores (Bao, 2008). The mechanics baseline exam that was given was used as a pre and post-test during the semester. By allowing the students to choose and giving them all of the solutions it allows the students to focus on the concepts with which they have the most difficulty.

Similarly, Boon Leong Lan a professor of Physics at Monash University in Selangor, Malaysia has also used a more flexible method of homework to motivate his students to be deliberate about their study time. Professor Lan does not collect homework for credit, instead, he gives the students one to two weeks to complete a homework set before coming to a tutorial class where the students have the opportunity to work through problems. Then, at the beginning of each tutorial he gives the students a 10 minute quiz on a random problem from the homework assignment (Lan, 2011). Once the students have completed the quiz they immediately go over the assignment and any other questions that the students may have from the homework. This is a way for the students to receive instantaneous
feedback about how they are doing on the assignment, instead of waiting a few days for the professor to grade it. Lan does not only give a pre-tutorial quiz, but he also gives the students another quiz at the end of the tutorial which encourages the students to actively participate when reviewing the problems because there will be a quiz with a problem very similar at the end of the session. At the completion of the semester, Professor Lan gave the students a survey asking the following two questions: “1) The beginning-of-tutorial quiz (on one of the homework problems) motivated me to try solving all homework problems before the tutorial. 2) The end-of-tutorial quiz (on a new problem) motivated me to learn during the tutorial how to solve problems I did not know how to solve” (Lan, 2011, pg 581). The graph below shows that approximately 87 percent of the students were motivated by the quizzes to complete their assignments before the tutorial.

FIG. 6. demonstrates the percentage of students and their rating of each question (Lan, 2011, pg 581).
For high school and college students the research has shown that just by increasing the amount of homework students complete can lead to mixed results. Some students, such as the high aptitude students from the study by Kontur, and the 25,000 students that were studied in the NELS study showed that increasing homework can lead to higher exam scores. Other studies, such as the study completed with low aptitude students by Kontur showed that more homework can actually decrease test scores with low aptitude students. Ericsson's study of a shorter amount of time on homework with deliberate practice was shown to increase students' abilities. Lastly, the sources listed in this section emphasized extrinsic motivation for students, such as grades and test scores. Each homework method used tried to increase the students' confidence and ability to have success to reach those extrinsic goals.
Methodology

Student Population

The participants for this study included 71 high school students (27 girls and 44 boys) enrolled in Introductory Physics at Geneseo High School in Geneseo, IL.


The students were divided into three separate sections containing 25, 24, and 22 students. The data taken for this study spanned for one semester and included...
topics dealing with Newtonian Mechanics. Some statistics of Geneseo High school, which are highlighted in FIG. 7., include a 95% graduation rating, an average class size of 19 students, average attendance rate of 96% and contains a total of 833 students, with the vast majority of the students being caucasian. During the 2013-2014 school year Geneseo High School had an average of 70% of the junior class meet or exceed on the PSAE, 16% above the state average. Many of the students that take physics are on the upper end of these averages and are typically higher performing students.

**Homework Methods**

During the course of this study the students were not given credit for completing their homework assignments, however, students were still given worksheets and text-book problems to supplement their learning throughout the term. To assess students’ progress on the concepts, the students were given homework quizzes the following day after each homework assignment was due (approximately 2-3 times per week). The students were not allowed to use their notes on the quizzes, only the homework problems they completed. A homework quiz consisted of one or two questions directly from the previous night’s assignment with the same wording but different numbers. A homework quiz could be a problem, conceptual question, or a combination of both. The students were given approximately 5 minutes at the beginning of class to complete the homework quiz and then the students would trade with a partner and the solution to the problem would be demonstrated for them on the white board. If the student got the correct answer and showed all of
their work they would receive 5 points, decreasing from there depending on the quality of their work and how close they were to the correct answer. Homework quizzes were designated as 15% of the students' overall grade in the course. The decision to make homework quizzes worth 15% of the overall course grade was because Kontur found that 15% is the optimal percentage to get students to complete the maximum amount of homework (Kontur, 2014). During the semester the students completed 15 homework quizzes for a possible 75 points. Following the homework quizzes the solutions to the complete homework assignment would be posted online for the students to review. An example of a homework quiz is located in (Appendix A). Sample homework assignments are also included in (Appendix B) and (Appendix C) to demonstrate the type of problems that students complete before taking their homework quizzes. Typically, homework assignments would include 2-3 basic level questions, 2-3 mid-level questions, and 2-3 more complex problems connecting more than one concept at the end of the assignment. This helps students gradually increase the difficulty of problems they complete and gives them an idea of their level of understanding of the problems.

Students' average exam scores and final exam score was also included in the data for this research. Each exam was composed of approximately 30-50% conceptual multiple choice or short answer questions and between 50-70% problems. A total of four exams were given during the course of the term and were used to calculate the average exam score for each student. To examine the students' progress and long-term retention of the concepts, the students took the Force Concept Inventory (FCI)
at the beginning and at the end of the school year. The FCI is based solely on Newtonian Mechanics and these concepts are only taught during the first semester of this physics course. It was given at the end of the course to see how well the students internalized the physics principles and if they could still apply the information after not specifically using it for almost four months. The Force Concept Inventory was designed to focus on force concepts such as, Newton’s three laws of motion, forces, friction, the superposition principle, and kinematics. The FCI contains 30 multiple choice questions with one correct answer and four other incorrect answers that make sense, but deal with the students’ misconceptions. For example, (Appendix D) gives a question from the FCI dealing with a car pushing a truck. This uses Newton’s Third Law that states, “for every action there is an equal and opposite reaction.” The correct answer to the question is (A) explaining that the force the truck feels from the car and the force the car feels from the truck are equal but opposite according to Newton’s Third Law. Many students would believe that the force from the car on the truck is greater because it is the car that is pushing the truck. Many students have a difficult time internalizing these concepts and don’t realize that when they push something, they also feel the same force back on them from the object. This test was developed to help students identify their misconceptions and to try to help them learn from those mistakes. The FCI was used in this study to assess student improvement and internalization of the concepts when compared to the percentage of homework students completed during the duration of the semester.
Another assessment that was used is the ACT. The students' math and science ACT scores were used to evaluate each student's aptitude towards math and science. The average of science and math ACT scores ranged from a 17 to a 33 between the 71 students. The students were broken into three groups based on their ACT scores. The groups were separated as follows: high aptitude (top 25% of the class), medium aptitude (middle 50% of the class), and low aptitude (bottom 25% of the class). The high aptitude students had a range of math and science ACT scores from 26.5 - 33, the medium aptitude students ranged from 23.5 - 26, and the low aptitude students ranged from 17 - 23. Each of these groups were tested to find the relationship between how much homework they completed and their average exam score during the course of the semester.

At the end of the term students were asked to complete a survey (Appendix E) about the flexible homework strategy based on taking homework quizzes and not turning in assignments. One question was an estimate of how much homework they completed throughout the term. To make this estimation the students opened up their folders and took out their homework assignments from the term and estimated the total percentage of problems that they completed during the term. The scale ranged from 0 - 25 percent, 25 - 50 percent, 50 - 75 percent, and 75 - 100 percent of the problems assigned during the semester. The students were also asked with what frequency they reviewed the solutions to the problems online after the homework quizzes were given. The scale for this answer included: 1 - never, 2 -
rarely, 3 - most, 4 - all. The students wrote their names on the surveys and turned them in so their survey answers could be correlated to the remainder of their data.

**Results**

The data in this study analyzes correlations between the percentage of homework completed and homework quiz scores, average exam scores, ACT math and science scores, final exam scores, and FCI scores. The varying science aptitude levels are also specifically analyzed to determine any relationship between the amount of homework completed and exam scores depending on their scientific aptitude. The following figures show the specific data collected.

![Graph showing HW Quiz Score in Relation to Percent of HW Completed](image)

![Graph showing Average Test Score Based on Percent of HW Completed](image)

**FIG. 8.** Plots the average homework quiz score and average exam score against the percentage of homework problems completed. Standard error bars are displayed in the graphs.
Fig. 8. Displays the correlation between the percentage of homework completed and the number of points scored on homework quizzes and the average score on unit tests. Due to the fact that the standard error bars overlap on the graphs, this demonstrates that there is no significant difference between the percentage of homework completed and the average exam scores. However, there is a trend that the more homework that was completed the better students scored on exams and homework quizzes. Students that completed 75 – 100 percent of the homework scored statistically higher on the homework quizzes than those students that completed 0 – 75 percent of the assignments as shown by the standard error bars.

**FIG. 9.** Demonstrates the average exam score against each student’s average homework quiz grade and average science and math ACT score. A line of best fit is included.
The data from FIG. 9. was expected when completing this research. The best fit line on the graphs confirm the assumption that students who score better on the homework quizzes and that earned the highest ACT scores would receive the highest average grades on the exams. Both of the graphs have a p-value < 0.001 and are statistically significant. This correlation could be attributed to the confidence level of students that did well on the ACT and on the exams. Students that are confident in their abilities may be more likely to perform at a higher level on summative assessments.
FIG. 10. Demonstrates the average final exam score and average math and science ACT scores when compared to the percentage of homework completed by the students. Standard error bars are included in the graphs.

The data observed in FIG. 10. demonstrates the opposite result of the previous figures. This data shows an inverse relationship between the amount of homework completed by the students and their average ACT score between math and science and their final exam score. There is no significant difference between the scores in
either of the graphs, however, students that completed between 0-25 percent of their homework assignments achieved the highest scores in both categories.

![Average Exam Score Based on Frequency of Solution Review](image1)

![Final Exam Score Based on Frequency of Solution Review](image2)

FIG. 11. Compares the final exam and average exam scores in relation to the frequency with which they reviewed the homework solutions online. Standard error bars are included.

The two graphs in FIG. 11. show the correlation between how often students reviewed the homework solutions online after the homework quiz and their performance on both the unit exams and the final exam. The scale for the frequency of solution review is as follows: 1 – never, 2 – rarely, 3 – often, 4 – always. There is no statistical relationship in either graph, however, in the second graph there is a
trend that as the frequency of homework review increased the students performed better on the final exam. The reason that the standard error is greatest in the final bar is due to the fact that there were fewer students in that category and a wider range of scores.

![Graph](image)

**FIG. 12.** Average improvement on the FCI between the beginning and end of the 2014-2015 school year based on the percentage of homework completed is displayed in the top graph. The second graph displays the average FCI score on the second attempt based on the percentage of homework completed throughout the term. The error bars represent standard error.

According to FIG. 12., the students who completed 75 - 100 percent of their homework problems received the highest average improvement with an average increase of 4.25 out of 30 questions. However, when standard error was calculated
there was no significant difference demonstrated between any of the four groups. The FCI was given at the beginning of first semester and at the end of the second semester to test students’ long-term retention of mechanics concepts. The second graph demonstrates the average score students received on the FCI at the end of the semester based on the percentage of homework that they completed throughout the term. Once again there is a trend that the more homework students completed the better they performed on the FCI on average, however, there is no statistical difference. This data is similar to the physics class of 2013-2014 when every homework assignment was collected and graded during the term. That year 78 students took the FCI at the beginning and at the end of the school year receiving a pre-test average of 7.5, a post-test average of 11.61, and an average increase of 4.11 points. The 2014-2015 students focused on for this study scored an average of 6.84 on the pre-test, and the 75-100 percent homework group scored an average post-test of 10.63. Even though the 2013-2014 group scored approximately one point higher on the post-test, they also averaged one point higher than the 2014-2015 group on the pre-test and showed an average improvement .14 lower than the students that completed 75-100 percent of their homework in 2014-2015.
FIG. 13. Breaks students into high, medium, and low aptitude groups and shows their average exam score compared to the amount of homework completed for each student. A line of best fit is included for each graph along with the equation.
The students' average ACT math and science scores determined the aptitude for each individual student. The graphs represent the percentage of homework completed for each student as follows: 1 represents 0 – 25 percent, 2 represents 25 – 50 percent, 3 represents 50 – 75 percent, and 4 represents 75 – 100 percent. The high aptitude students contained approximately the top 25 percent of the class and the best-fit line showed a positive slope with increasing scores as the percentage of homework increases, however, the slope was not statistically significant with a p-value equal to 0.285. The middle aptitude students represented the middle 50 percent of the student population and showed a statistically positive correlation between homework and test scores with a p-value equal to 0.0364. Finally, the low aptitude students showed a slight negative correlation between the percentage of homework completed and exam scores, however, it was not statistically significant with a p-value equal to 0.991. With a p-value this close to one, the correlation seen with the low aptitude students is negligible.

Discussion of Results

As stated earlier in this paper, many teachers and professors believe that homework is an important tool for improving the achievement of their students. After analyzing the trends from the data in the previous section, it is clear that by completing a greater amount of homework leads to higher homework quiz scores, FIG. 9. Also, FIG. 8. does not show any significance between exam scores and the percentage of homework completed but there is a trend that on average, students who completed
greater amounts of homework received higher test grades. Also, in FIG. 12, students that completed greater amounts of homework had the greatest improvement and overall best FCI score by the end of the term. Unfortunately, there is no significant relationship demonstrated with the FCI scores, but there is a trend in the data. This data leads me to believe that on average, there is a slight correlation between the amount of homework that is completed and the performance of students on assessments.

When the students were separated into high, middle, and low aptitude levels based on their math and science ACT scores, there was no statistical evidence that the percentage of homework that they completed impacted their exam scores. However, there were some slight trends in the data that correlated with Kontur’s study based on aptitude. Kontur found that high aptitude students benefit from completing a greater amount of homework, and that a greater amount of homework has a negative impact on low aptitude students (Kontur, 2015). The data displayed in FIG. 13 demonstrates a similar trend. The high aptitude students evaluated in this study showed a slight increase in test scores the more homework they completed. One reason for this trend may be that high aptitude students have a greater ability to connect different concepts together and to build off prior knowledge at a higher rate than lower aptitude students. The low aptitude students in the study showed a slight negative correlation between the percentage of homework they completed and their exam scores. It is believed that these students may struggle with concepts learned in class and can be confused when they have to connect multiple concepts.
into one problem. Thus, if they are confused completing more problems will not assist them in learning the material, but it may have a negative impact and reaffirm some of the students' misconceptions. This result could call for a change in the teaching of these students. One option would be to differentiate instruction for these students by giving them a greater number of examples and explanations during class while higher-level students are allowed to work individually or in small groups after only one or two examples. This could allow for the high level students to practice on their own and come to their own conclusions while also giving the lower level students the support they need to succeed. The middle level students in this study showed a significant improvement on exam scores from completing greater amounts of homework. In Kontur's study the middle aptitude students demonstrated mainly negative correlations between homework and exam scores. The discrepancy could be based on the level of difficulty of the material and the rate of the class. Kontur completed his study on college students in a calculus based course, which would move at a much higher rate than a high school course. In high school, students have an easier time catching up if they get behind, however, in college it is more difficult because of the rate at which concepts are covered. Thus, it is my belief that the middle level students increased their scores by completing more homework problems because there was opportunity to take their time and learn the material at a slower rate than at the college level.
Discussion of Student Surveys

Throughout this class the students completed homework assignments purely for practice and the homework assignments were not graded. However, the students did have a homework quiz over one or two questions based on each assignment. Typically the questions were similar to the assignment with only the numbers changed. The students were able to use their homework as a resource on the quiz. Immediately following the completion of homework quizzes in class the students would trade quizzes and they would be graded. The students would follow along with the instructor as the solution was explained and the students would mark the quizzes as correct or incorrect. The instructor would specifically grade each one after class and would designate how many points each student should receive based on the correctness of the quiz. By reviewing the answer immediately after the students took the quiz it gave the students instantaneous feedback on the assignment and let the students know if they were completing the assignment correctly or had some misunderstanding. Also, after the quiz if students had questions over any other problems from the assignment they would have a chance to ask questions. After the students completed the homework quiz, the complete solutions to the assignments were posted online so the students could review all of the solutions to the homework on their own. The instant feedback that the students received from the online solutions and the explanation of the homework quiz was much more effective than the students waiting one to two days for the teacher to grade the assignments. This led to more self-reflection by the students on what they
were doing correctly, and what concepts they should focus their study time on.

According to the data shown in FIG. 11., the more assignments the students reviewed online the higher final exam score they achieved. There was no significant relationship from FIG. 11. most likely because the group that looked up the solutions to every assignment was small resulting in a large standard error. However, I do believe that by giving the students the solutions after each assignment helped the students that took the time to look up the answers perform at a higher level on the final.

At the culmination of the data collection for this study the students were asked to complete a survey. This survey asked the students a series of questions about the method of assessment involving homework quizzes vs. students completing every assignment and every assignment being graded by the instructor. The first question asked the students to give an explanation as to why they did not complete all of the questions to each assignment if they did not do 100 percent of the problems. The typical explanation that was given by the students was that by the time they completed homework from other classes, practice for other activities, family time, and work they simply did not have time to do the entire physics assignment. Many of the students taking physics were in more than one AP course and also in advanced math courses so they typically had homework in other areas every night. Another explanation that students gave was that they skipped the problems they knew how to complete and focused on the problems that they struggled on. Many students explained that they did not want to waste their time doing problems if they
already knew how to do it. One of the goals of this strategy was to allow students to focus their study time only where they needed the most assistance.

Another question from the survey asked, "Do you want to continue the current method of teaching being used in physics where homework quizzes are given instead of each assignment being graded?" Out of 71 students 68 of them wanted to continue completing homework quizzes with optional homework. The students were also asked to explain why they liked or disliked the homework method. The students that stated that they would prefer being graded on every assignment said, "I do not see the point in completing homework if I am not going to be graded on it." I would agree that many students feel this same way. They do not believe that they should do something if they are not getting credit for it. This goes back to there being a lack of extrinsic motivation, such as grades, for completing work. However, what many students fail to realize is that the assignments are there to prepare them not only for the homework quizzes, but for the exams as well. Several students that liked completing homework quizzes gave this statement, "Taking homework quizzes actually shows if we can apply our knowledge of the subject to a given problem instead of copying the homework off of someone else. Doing homework quizzes encourages us to do our own work because there is no consequence for getting one wrong on the homework." There were four or five students that gave a similar answer to this student about reducing the frequency with which students copy homework. This study was not meant to reduce the frequency with which students
copy assignments, but by reducing the pressure to complete the entire assignment, it alleviates the students' urge to cheat.

The final question that the students answered asked, "In your opinion, were you able to learn more effectively from daily homework quizzes and checking the solutions online than you are from the more traditional way of turning in all assignments?" Once again, many similar answers were given by the students, such as, "Not every teacher gets the homework back to you fast enough, using this method I get instant confirmation whether I am doing the assignment right or not." With this method of giving assignments and posting the solutions online students are able to receive instant feedback from the instructor. With the traditional method of homework, it takes a good teacher one to two days to return the assignments. As a teacher, I have found that sometimes after two days the students have already forgotten what they understood or did not comprehend on an assignment. Also, it is difficult as a teacher to write a detailed explanation on every problem as to why the students may have missed a question. This method gives the students the tools to look up all of the solutions to the problems and reflect if they missed a question by analyzing the solutions themselves. Another student said, "I like homework quizzes because it allows me to focus on the problems that I need practice on and doesn't waste my time filling out a whole worksheet that I already know how to do." This was a common opinion among the students. Many students felt that by making the assignment optional they could focus only on the problems where they have the most difficulty. If the students were assigned the entire worksheet, they would have
to spend much of that time doing problems that they find easy. The homework assignments given in this class were similar to the way most teachers give assignments. There are problems at varying difficulty levels. Some students easily understand how to do the easy problems and can only focus on the hard problems. In the literature review of this study the topic of "deliberate practice" was discussed. If students are able to focus for a shorter period of time on more difficult problems instead of easy problems this is making their study time more deliberate, thus allowing the students to focus more critically for a shorter amount of time.

**Conclusion**

Assessment methods continue to be a topic that is commonly debated among today's educators. It is clear that there are a variety of methods varying from traditional to more flexible methods of assessment. Based on the results of this study there is no significant data that suggests the homework method described in this study either increases or decreases the achievement of high school physics students. However, there were some trends in the data that showed that high and middle aptitude students showed an increase in achievement by completing a greater number of homework problems. Unfortunately, a different strategy may need to be developed to increase the achievement of low-level students in physics classes as their performance on exams decreased when more homework was completed. This trend agreed with Kontur's study at the United States Air Force Academy with their introductory Electricity and Magnetism course where high
aptitude students improved by increasing their homework load, and low-aptitude students' performances decreased.

A second goal of this study was to give students the opportunity to be more deliberate about their study time and to focus on the concepts that they found to be the most difficult. By giving the students the solutions after they completed the assignments it also allowed students to be more reflective about their own learning and gave them the chance to analyze what they were doing correctly or incorrectly. The data demonstrated that students that the more solutions the students viewed online the better they performed on the final exam. Through student surveys it was found that the students' stress levels were decreased because they were more focused on learning the material than they were about just finishing each assignment. Another benefit to this method was that it reduced the frequency of cheating on assignments and forced the students to take ownership of their own work on the homework quizzes. The students had a more positive outlook on the way class was run and found the assignments to have more purpose if they could focus solely on the areas where they were struggling. I believe that the homework method discussed in this study has many benefits and is worth continuing to use in my classroom.
References


A pilot wants to fly a plane at 450 km/h directly North. The wind is blowing at 70 km/h from the East. Find the magnitude and direction of the course the pilot should fly.

\[ R = \sqrt{450^2 + 70^2} \]

\[ R = 455.4 \text{ km/h} \]

\[ \tan \theta = \frac{70}{450} \]

\[ \theta = \tan^{-1} \left( \frac{70}{450} \right) \]

\[ \theta = 9.84^\circ \]

The pilot should fly 455.4 km/h at 9.84° E of N or at 81.16° N of E.

This homework quiz is the same question as #4 from the assignment in Appendix B with the numbers altered.
Appendix B

Vectors Worksheet

1) Find the resultant of the following vector pairs.

\[ \begin{align*}
12N & \quad 7N \\
\mathbf{i} & \quad 19N \\
8N & \quad 11N \\
\mathbf{j} & \quad -3N
\end{align*} \]

2) A force of 12 N acts on a box at 60 degrees above the horizontal. What is the horizontal and vertical component of the force?

\[ \begin{align*}
\sin 60^\circ (12N) &= y \\
y &= 10.39 N \\
\cos 60^\circ (12N) &= x \\
x &= 6 N
\end{align*} \]

3) Determine the magnitude and direction of the velocity of a plane that is flying west at 100.0 km/h with respect to the air while the wind is blowing toward the north at 65 km/h relative to the ground.

\[ \begin{align*}
\sqrt{65^2 + 100^2} &= R \\
R &= 119.3 \text{ km/h, 33° N of W or 57° W of N} \\
\tan^{-1} \left( \frac{65}{100} \right) &= 33^\circ
\end{align*} \]

4) A pilot wants to fly a plane at 500 km/h directly north. The wind is blowing at 90 km/h from the East. Find the magnitude and direction of the course the pilot should fly.

\[ \begin{align*}
\sqrt{90^2 + 500^2} &= R \\
R &= 508 \text{ km/h, 10.2° E of N or 79.8° N of E} \\
\tan^{-1} \left( \frac{90}{500} \right) &= 10.2^\circ
\end{align*} \]
5) A soccer ball is rolling east at an average velocity of 6.0 m/s when a kick deflects it to the north at an average velocity of 7.0 m/s. What is the magnitude and direction of the ball's change of velocity.

\[ R = \sqrt{7^2 + 6^2} = 9.22 \text{ m/s} \]

\[ \theta = \tan^{-1}\left(\frac{7}{6}\right) \approx 49.4^\circ \]

In the above example, question 1 and 2 are introductory level with students learning how to add and subtract vectors and using trig functions to find the adjacent or opposite side of a triangle. Question 3, 4, and 5 are mid-level questions because the students must draw a triangle using the two vectors and find the resultant. Lastly, question 6 is at a higher level because the students are not given a right triangle in the problem. Instead, they must learn how to create a table and add the (x) and (y-components) of the vectors separately. Then create a new triangle with the total (x) and (y-components) to find the resulting vector.
Appendix D (Hestenes, 1992)

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.

Appendix D contains a sample question from the FCI.
Appendix E

Physics Semester 1 Survey

1. Based on percentage, how much of the homework did you complete this past semester?
   a. 0-25%
   b. 25-50%
   c. 50-75%
   d. 75-100%

2. If you did not complete all of the assignments please give a short explanation as to why you did not complete all of the homework assignments.

3. How many times did you use Mr. Deets' website to look up the solutions to assignments during first semester?
   a. never
   b. rarely
   c. most of the time
   d. I looked up every assignment

4. Do you want to continue the current method of teaching being used in Physics where homework quizzes are given?
   a. Yes
   b. No

5. Please give your reasoning as to why you like or disliked taking homework quizzes instead of the more traditional method of turning in every assignment.

6. In your opinion, are you able to learn more effectively from daily homework quizzes and checking the solutions online than you are from the more traditional way of turning in all assignments and waiting for the teacher to grade them? Explain.

7. Is there anything that Mr. Deets could do differently next semester to help you learn more effectively?