The Impact of Competitive Collaborative Game Play on Achievement and Attitude in Advanced Placement Physics

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Abstract

The United States has been falling behind in science literacy when compared to other countries around the world. Even though the U.S. federal government has been funding STEM programs to help close this gap, research has shown little to no improvement directly related to funding (GAO-06-114 Federal STEM Education Programs, 2005). The U.S. is also failing to entice enough students into STEM careers, leaving increasing opportunity for this market to be filled by students from other countries, especially from India and China (Gandjour, 2008). The inclusion of physics games in a physics course may improve attitudes, increase affinity, and improve achievement in physics allowing more students to pursue STEM careers. This study looked at the impact of playing collaborative physics games in an AP physics course on student achievement and attitude towards physics. Students played competitive physics games (PhysTec) in collaborative teams. Their pre- and post-quizzes, as well as chapter tests were analyzed to determine any changes in achievement. Surveys and Questionnaires, given before and after several games were played, were used to determine any changes in attitude. Findings were mixed. Quantitative data showed both increases and decreases in achievement. Qualitative data showed an increase in positive attitudes toward physics. Qualitative data suggested that students felt more prepared for test and a greater affinity for the class after playing the games. These games could have similar productive results in classes with students who enjoy competition, such as AP and gifted students.

The Impact of Competitive Collaborative Game Play on Achievement and Attitude in Advanced Placement Physics

The Program for International Student Assessment (PISA) is a system of international assessments that measures 15-year-olds' performance in reading literacy, mathematics literacy, and science literacy every 3 years in more than 30 countries (Baldi, Jin, Skemer, Green, & Herget, 2007). Researchers studying the results of the PISA assessments found that the United States ranked below average in combined science literacy (Baldi, et al., 2007). In the modern global market place, it is in the best interest of the United States to be performing with superior science literacy. Additionally, the Trends in International Mathematics and Science Study (TIMSS), published in 2004, showed the United States at a lower level of achievement than many East Asian countries. Based on this result, the media, researchers and policymakers in the United States have often worried about a decline in US competitiveness in mathematics and science (Gandjour, 2008). While students are performing below the level of their international peers, the federal government has tried to stimulate interest and achievement in science, technology, engineering and math (STEM) in the United States by funding $2.8 billion dollars into STEM programs (GAO-06-114 Federal STEM Education Programs, 2005). Although a lot of money has been injected into educational programs, the United States is still failing to entice large numbers of students into STEM based college majors and careers. Even though there has been an increase in the number of women pursuing STEM degrees, a smaller percentage of college students overall are graduating with STEM degrees (GAO-06-114 Federal STEM Education Programs, 2005). Unfortunately, with a large growth in science and technology jobs worldwide, this market will continue to leave the United States unless something can be done to attract more students in the United States to follow STEM careers.

In my opinion, two things must be accomplished in order to promote STEM careers to students in high school: they must experience a greater affinity for science and they must experience greater success on measures of science achievement. I have always found that students will continue to pursue academic areas they find interesting, fun and challenging. Subsequently, I have tried to create a physics course that includes those elements. I have attempted to reduce the rigidity of the science classroom, to encourage collaborative learning, and to allow flexible learning timelines. The changes I have made are based my personal and professional opinion on ways to improve student performance. There is very little direct guidance for teachers on what learning characteristics should be emphasized. Despite its importance, little research has attempted to understand what influences teachers to promote certain goals in high school classrooms (Deemer, 2004). My next goal is to further improve student affinity for physics and at the same time improve achievement.

The question I asked myself is how do I make physics fun, challenging and something students look forward to everyday. I decided that I would try to create a physics based educational game. Games are played in every corner of the planet, by people of every age. They remain an important part of our lives from childhood into our golden years for the simple reason that they are fun and bring joy and achievement into our lives. Games do more than just entertain us, they also teach us skills. "Games are not just a diversion to children, but an integral part of their social and cultural lives" (Rieber 1996, p. 54). Even animals play games to learn to hunt, hide or escape. We grow up playing a wide variety of games: sports, cards, board, puzzle, dice, guessing, word and more. We play alone, on teams, for fun, for challenge, for glory or even for employment. We are so involved with games that we even honor our greatest game players by calling them heroes. This is especially true in the realm of competitive sports games.

We hand out medals to the best athletes in the world. Jerseys of some of the best sports game players can be seen being worn by their fans in most countries around the world. It is obvious to me that we reward those who can master competition. We also spend billions of dollars following their achievements and sharing in the joys of their triumphs. Everywhere you look in the world, people invent, and play games. We love games, whether they be sports, board games, puzzles or video games.

I wanted to bring the intrinsic fun of game play into the physics classroom for the purpose of learning, and increased motivation and affinity. I wanted to see if the highly competitive game play could help prepare students for the Advanced Placement (AP) exam. I have also observed the importance of collaboration in the physics classroom and wanted to test the effects of teamwork based game play.

There are two questions that this study is trying to answer:

1. Does playing competitive, collaborative, problem-solving games improve achievement in physics for AP physics students?
2. Does playing competitive, collaborative, problem-solving games improve AP physics students' attitudes toward physics?

Literature Review

In attempting to create a meaningful physics game for my students, I investigated three key components that I wanted to include within the gaming structure. I wanted a game that students could share ideas and collaborate on possible solutions. I wanted a game that was competitive with high stress levels like what the students would feel during the AP physics exam near the end of the course. And finally, I wanted the sense of belonging to a team that comes for certain styles of game play, such as sports games. I researched primarily in these three areas to help plan and design my game as well as the execution of the study.

Collaboration

While all students need individual practice solving problems in physics, collaboration can improve problem solving strategies and reduce anxiety involved. Harskamp and Ding (2006) conducted research on students in Shanghai to determine a best practice method for solving physics problems. Their results found that a structured collaboration generated the greatest student achievement. These results agreed with previous studies which showed that children who had previously worked as collaborative pairs on problem solving in physics were twice as successful on a knowledge test as children who had had the same amount of experience working alone (Blaye, Light, Joiner, & Sheldon, 1991). Therefore, students who practice physics problem solving together in groups are likely to be more successful on future tests.

Another benefit of collaboration is an increase in the level of on task behavior while reducing behavior problems. By studying the influence of mastery and performance goals on the nature of children's collaborative participation while playing a problem-solving game with a peer, Harris, Yoill and Luckin (2008) found that due to the collaborative grouping there "appeared to be a high level of task focus and engagement which was indicated by the large proportion of contributions oriented towards problem solving and the low level of off-task behaviour" (p. 368). Thus grouping students together can increase students' engagement and reduce off task behavior.

Although grouping is important, the type of grouping does not to appear to be critical. Cheng, Lam and Chan (2008) investigated the roles of group heterogeneity and processes in project-based learning. With 367 groups taken as the unit of analysis, their results showed that group heterogeneity, group gender composition and group size were not related to the discrepancy between collective- and self-efficacy reported by the students. Furthermore, the study found that the quality of group processes played a pivotal role because both high and low achievers were able to benefit when group processes were of high quality. In a high achieving class like AP physics, the grouping, either homogenous or heterogeneous should not affect achievement.

In addition to better achievement, collaborative groups can increase social gains and improve affinity for a subject. Willis (2007) reported that cooperative learning has both cognitive and social gains that can be measured in performance as well as in brain activity. Willis found evidence of brain and neurochemical activity that supported the positive results she was having with the cooperative approach to middle school teaching. In addition to briefly relating her findings, Willis continued to give guidelines for successful collaboration in cooperative groups in the form of five characteristics for the group project.

• All members have opportunities and capabilities, frontloaded if necessary, such that different students can make their own special contributions.

• Students learn to respect each other as group members. Students experienced a greater level of understanding of concepts and ideas when they talked, explained, and argued about them with their group, instead of just passively listening to a lecture or reading a text.

• The group negotiates roles with guidance from the teacher.

• There should be more than one answer or more than one way to solve the problem or create the project.

• The activity should be intrinsically interesting, challenging, and rewarding.

(Willis, 2007, p. 7-8).

Well designed collaborative group activities provide both better achievement and better social skills, which could also include game play.

When it comes to physics students in particular, students prefer a mix of teacher lead lessons and student group work for difficult material. Students said that physics teachers typically present new material or solve problems on the blackboard, and this is what students want (Lavonen, Angell, Bymen, Henriksen, & Koponen, 2007). On the other hand, students would like to discuss difficult concepts and problems more, as well as work on problems and tasks in small groups. They would also like the teacher to lead the discussion when topics are discussed in the classroom (Lavonen, et al., 2007). By combining a mix of teacher led discussion and group work, which could include team games, within the physics classroom, students' preferences are met and affinity should rise.

Competition

In order to create a competitive game that creates a positive attitude and a drive to work harder, as opposed to an anxious attitude that leads to a lack of participation, I researched the components of competition that create both. Almost all competition has both positive and negative components. Some students thrive when results are ranked while others may disengage to avoid stress and failure. I investigated primarily how competition affects students in an educational setting. McMahon, Wernsman and Rose (2009) found that competition places students in rival positions and can create animosity within the classroom. Although results were based on elementary school children, their study found that students who perceive the classroom environment as conflictual, difficult, and competitive feel less connected to their schools and have a lower self-efficacy in math and science.

However, we live in a competitive world. Competition is part of everyday life and should be introduced in education to help students prepare for our current society. As adults, we compete in numerous ways such as for jobs and occupations, promotions, marriage partners, good grades in classes taken, and for leadership responsibilities in society, among others (Ediger, 1996). Students will continued be ranked and performance will be compared using one measure or another. Not only will students compete in college for grades, but beyond college in the world market for jobs. Currently, the United States is becoming less competitive overall, especially when viewed on the world stage. The Trends in International Mathematics and Science Study (TIMSS) compares mathematics and science achievement of school students around the world. The latest TIMSS data, December 2004, show that US students have a lower level of achievement than students from many East Asian countries – e.g. the world leader Singapore

(Gandjour, 2008). What will continue to change and be debated is the means by which we measure student success. Although our average math and science scores for students may be inferior, the top high school students in math and science in the United States are highly competitive with other countries (Gandjour, 2008).

The competition itself will always be present between students, schools, districts, states and nations. Within academically advanced classes (e.g., Advanced Placement) students adopt the competitive traits of their peers (Deemer, 2004). Competition is neither good nor bad, but it depends upon how it affects individuals. Ediger (1996) felt teachers might wish to encourage positive competition among individuals in the classroom setting. It is this positive competition that I wish to focus on. I have been involved in several formal academic competitions and have seen students become interested in related career fields. Formal competitions can help introduce and guide students toward future careers. Bishop and Walters (2007) found student activity in a formal competition (e.g. Science Bowl) leads to pursuing related post-secondary study. What is important is that the competition leads to positive attitudes and outcomes.

Ediger (1996) lists five characteristics of positive competition:

1. Those competing should be somewhat equivalent in talents, skills, and abilities.
2. Those competing should have positive attitudes toward each other
3. Those competing should have a desire to participate and learn.
4. Those competing should have definite goals to achieve in the competitive event.
5. Those competing should realize that not all individuals can be winners. Best it is if all pupils can be winners. This is definitely possible. (p. 207)

I used these characteristics as a blueprint for the design of my physics game, PhysTec. I tried whenever possible to reduce anxiety and increase positive attitudes using the competition design.

Game Play

There are many forms of game play and I wanted to select one that would have the greatest impact on achievement and improved attitudes toward physics. Much of the research I found discussed the use of computer games, but I chose to create a game that did not involve computers. I looked at the successful components within computer and other game play, and used those components in my design of the PhysTec game. In order to create a game that is valuable to learning physics, there are key elements that must be met.

Kiili's (2007) study found the following:

> Authenticity, collaboration and learning by doing were found to be most important characteristics of effective educational games. The role of the games was seen more like applying previously learned knowledge than studying totally new issues. Generally, properly designed educational games can be used in higher education to make complex theoretical knowledge more approachable. (p. 403)

When games are designed properly, abstract concepts are more attainable. By challenging students with real life problems that they can solve together, the challenge creates a positive learning environment. Students create proposals for solutions that are compared to other teams' ideas. This models how many companies, especially science based companies, compete for consumer dollars.

Most people enjoy playing games, which can be seen by the large number of sales and use of computer games, board games and card games around the world. It is still unclear to many researchers whether game play should be used as an educational tool. Researchers have turned up both positive and negative impacts of using game play as an educational tool. Students playing math games for learning, reported negative attitudes about the game in a survey; but when interviewed, discussed having positive learning experiences while playing the game (Bragg, 2007). Some students may have a hard time separating what they gained from the experience, from the anxiety encountered during the game play. This may explain the seemingly contradictory data given by the students.

Many games, especially video games, have gained a lot of attention as possible educational tools. Gros (2007) found that engagement and motivation are benefits of the use of games, but they are not enough for educational purposes. Still, there are advantages of game play. Digital games are user-centered; they can promote challenges, co-operation, engagement, and the development of problem-solving strategies (Gros 2007). This led me to believe I could create similar positive traits using a non-digital game format. My research into game play in education kept returning to computer based games, but my current needs did not align with a computer based game. I wanted greater student to student interaction as opposed to student to computer interaction.

Constructivism

I wanted the types of games played in the physics classroom to have elements of constructivism. Students should be allowed to develop their own solutions while applying basic rules and laws within physics. The game should be structured to challenge problem solving skills while allowing for the freedom of more than one possible solution. Problem-solving play was found to have no significant gender differences in preference or attitude, suggesting that this mode may appeal equally to children of both genders (Kinzie & Joseph, 2008).

By applying constructivist teaching practices, Yager and Akcay (2008) found students:

- learned basic concepts as well as students who studied them directly from the textbook.
- achieved as much general concept mastery as students who studied in a textbook dominated way.
- applied science concepts in new situations better than students who studied science in a more traditional way.
- developed more positive attitudes about science,
- exhibited creativity skills that were more individual and occurred more often.
- learned and used science at home and in the community more than students in the typical textbook dominated section. (p. 1)

Allowing students the freedom to find their own creative solutions, they develop more positive attitudes about science. Although constructivist elements are essential, Geleen, Wildy, Louden and Wallace (2004) demonstrated that students were confused by the lack of structure in a constructivist model and felt more comfortable in a teacher lead learning style, such as lecture and guided practice. Further, in the case of physics, ‘teaching for the test’ met desired outcomes, such as high achievement scores. In order to best serve students, the physics classroom must be a balance between teaching direct physics problem solving and creating scientific thinkers. The physics teacher needs to supply a definite structure in which the students may work. Students need freedom to explore alternative methods to solve a problem, but also, understand how to use current problem solving techniques in order to finish problems in a timely manner.

Methodology

The study took place at Westlake High School in Westlake, California during the fall semester of 2009. The study was conducted over a twelve week period. 79 AP physics students took part in the study with ages ranging from 15 to 18 years old. Students took part in a standard AP physics C (mechanics) course, but had the addition of physics games (PhysTec) added to the curriculum once per chapter for three chapters in the second half of the first semester. For the game, students were broken into groups of four to six students, forming approximately ten teams. The PhysTec game was played for one lesson per chapter (chapters three through five). Teams were presented physics based problems, projected onto a large screen in the front of the room, to solve in a given time frame. Teams constructed group answers on white boards and turned in the boards when finished with the problem. Teams earned points for correctly solving the problem as well as additional points for being the quickest to solve the problem. Points were deducted for incorrect solutions or not completing a solution in the time permitted. Questions resembled problems practiced in class that would appear on a chapter test, multiple choice style questions consistent with the AP exam, free response style questions consistent with the AP exam, laboratory problems, and conceptual problems. Time allowed for problem solving varied from two to five minutes depending on the difficulty and length of the solution involved. As a motivational factor, teams that ended the game with scores over a set minimum, received extra credit. The difficulty of the questions was moderate to high, so teams would typically fall short of the point minimum for extra credit. Out of the twenty teams between the two class periods that played the game, only about seven teams earned extra credit. The extra credit was typically equivalent to about 5 points out of an average of 1600 points for the semester or approximately

0.31% of the total grade. The game was designed so every team can win, but that the value of the "win" is greater for teams that finish faster. In order to promote full participation, each solution was to be authored by a different member of the team for each new problem. The team could offer suggestions, help calculate, and give instructions, but the author was the only one who could write the solution on the whiteboard. This was also designed to promote communication and to model appropriate approaches to solving physics problems by those more expert within the group. Data to determine achievement was gathered using pre- and post-quiz scores and chapter test scores. Data to determine attitudes toward physics and science in general was gathered using a survey, a questionnaire and focus groups. The beginning portion of the study used period four as the treatment group and period five as the control group. Unfortunately, after forth period talked to fifth period about the game, fifth period demanded that they too get to play the game. So, the second and third games of PhysTec were played by both classes and the data was analyzed using Two-Sample t-Test Assuming Equal Variances.

Results

Academic Achievement

Initially, I checked the impact of playing the competitive collaborative physics game, PhysTec, on the academic achievement of my students by looking at overall trends in chapter test scores from chapter two through chapter five. The trends were inconclusive. Both periods had relatively high scores over the entire period with trends showing both gains and losses in achievement according to their test scores (Figure 1). Since period four began treatment before period five, I was able to compare tests scores using period four as the treatment group and period five as the control group for the first session of PhysTec. I analyzed the averages in chapter test scores for my period four class who received the game treatment and the test scores

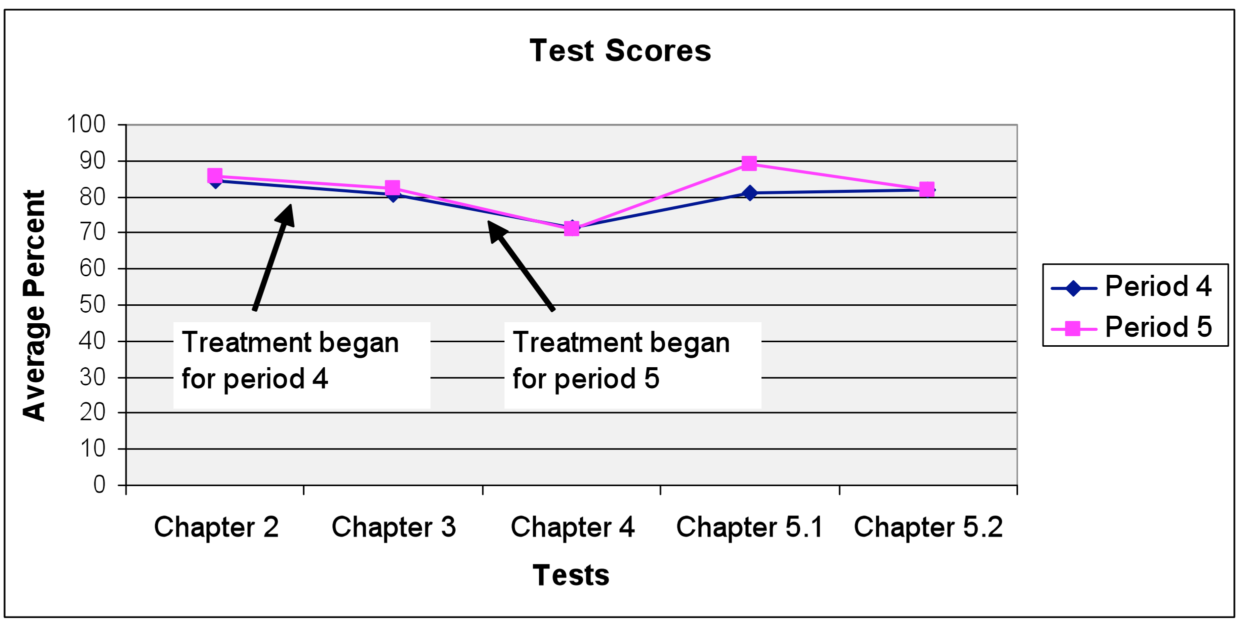

Figure 1. Average chapter test scores for period four and five.

for my period five class who did not receive treatment for this particular chapter. I used a Two-Sample t-Test Assuming Equal Variances to compare the results from a chapter test on one-dimensional linear motion to the following chapter test on two-dimensional motion. Period four's first exposure to the game occurred between these two chapter tests. Although both periods retained high averages overall (over 80%), there was a decrease in the average score for both class periods. There was a significant decrease in Period four's test scores after playing the game as shown in Figure 2 ($p < .05$). There was also a decrease in Period five's test scores, the control group for this portion of the study, but period five's decrease was not statistically significant.

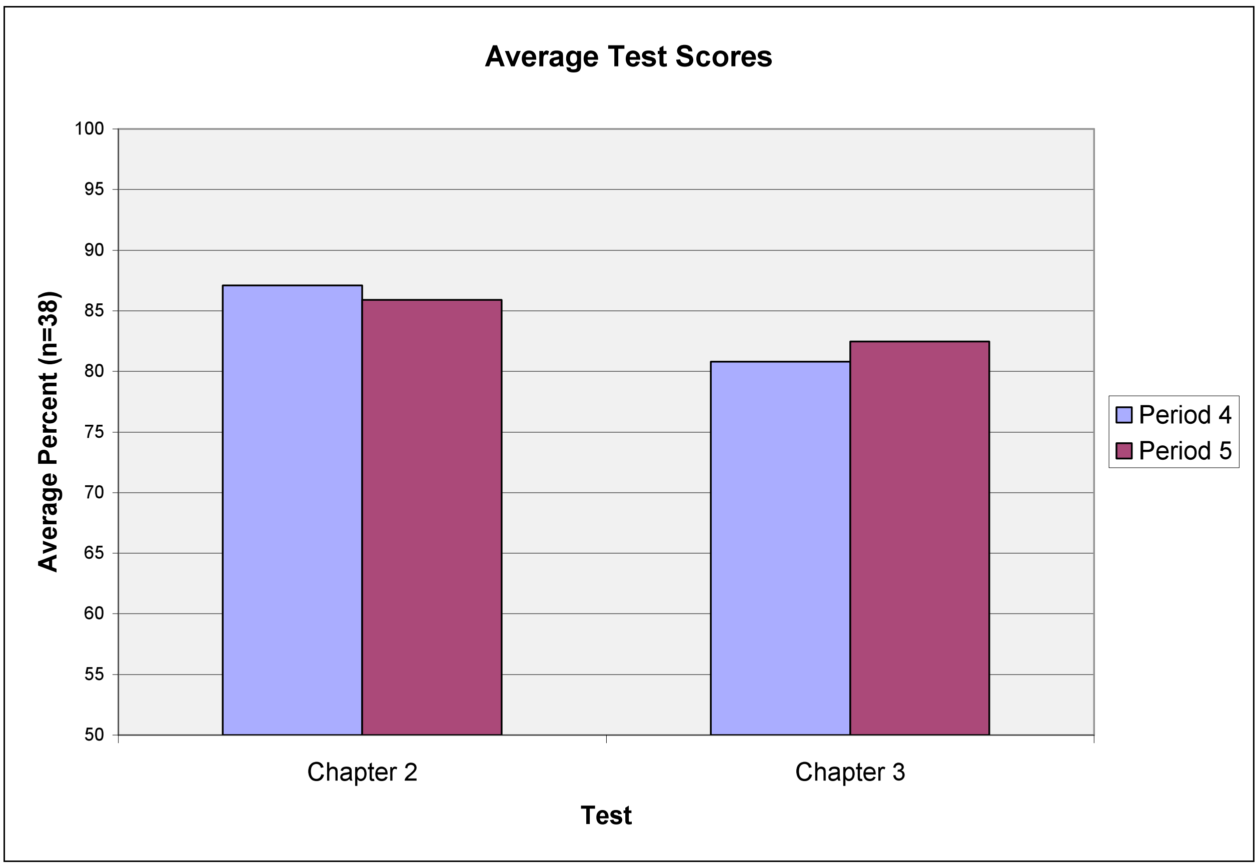

Figure 2. Average test scores for chapter two and three.

After chapter three, two-dimensional motion, period five was included in the treatment. Both periods participated in a pre and post quiz during chapter four on Newton's laws of motion.

In between the pre and post quiz, each class played one PhysTec game. In order to further test the impact of competitive collaborative game play on the academic achievement of my students I conducted a Paired Two-Sample t-Test for Means on the pre and post quizzes for both period four and period five students. Both periods showed significant gains in scores ($p < .05$, $p < .005$) as shown in Figure 3.

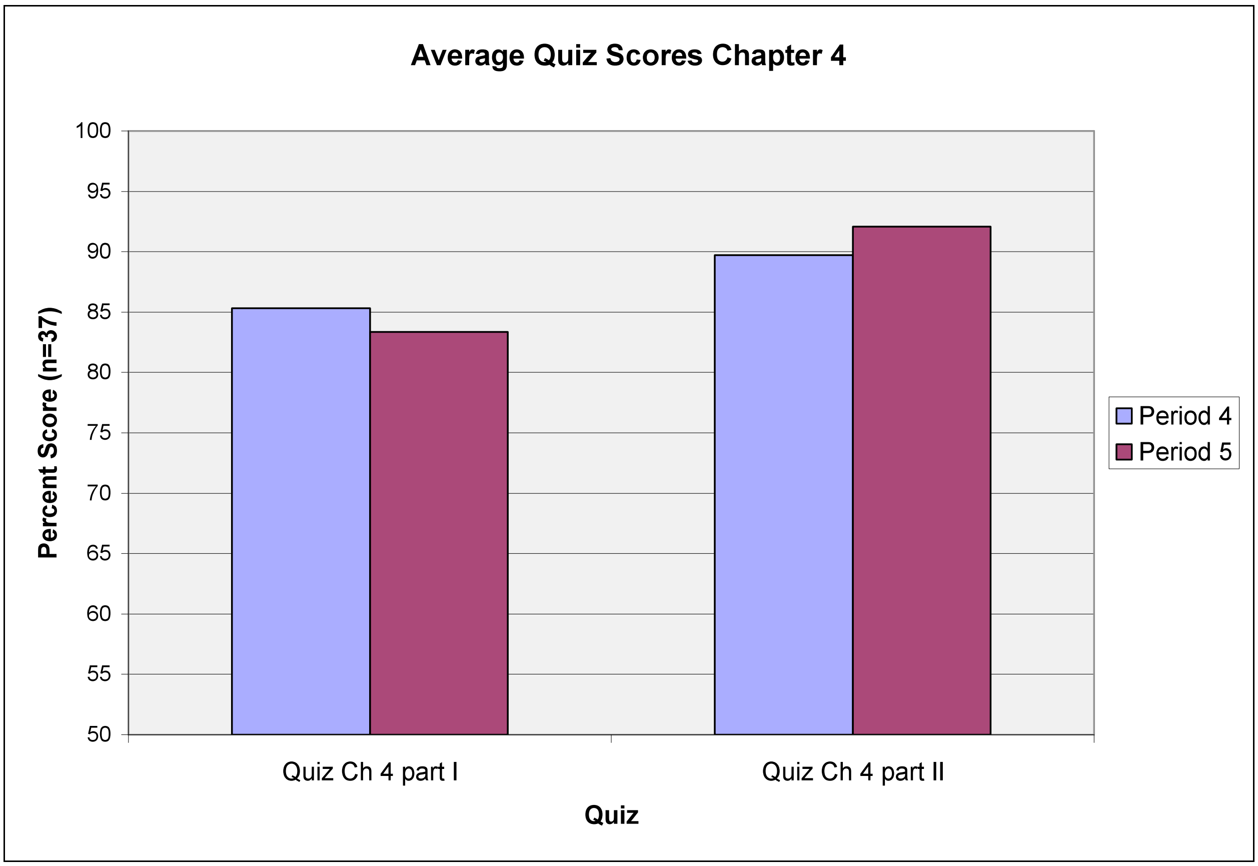

Figure 3. Average quiz scores for chapter four part I and part II.

I also analyzed data from another pair of tests later in the semester. I compared the averages between two tests within one chapter. Both class periods received the treatment, playing PhysTec for that chapter, between taking the two tests. For the fourth period class, this was their third exposure to the game. For the fifth period class, this was their second exposure to the game. The tests were both based on concepts involving work and energy. The chapter 5.1 test was based on basic ideas relating to work, potential energy and kinetic energy. The chapter test 5.2 was based on more comprehensive ideas involving the work, potential energy and kinetic energy including conservation of energy, within a complex and dynamic system. Both classes retained high average scores overall (above 80%). The period four class showed a small, but not statistically significant increase in achievement. The period five class also showed a decrease in achievement between test chapter 5.1 and test chapter 5.2, but only period 5 showed a statistically significant decrease ($p < .05$) as shown in Figure 4.

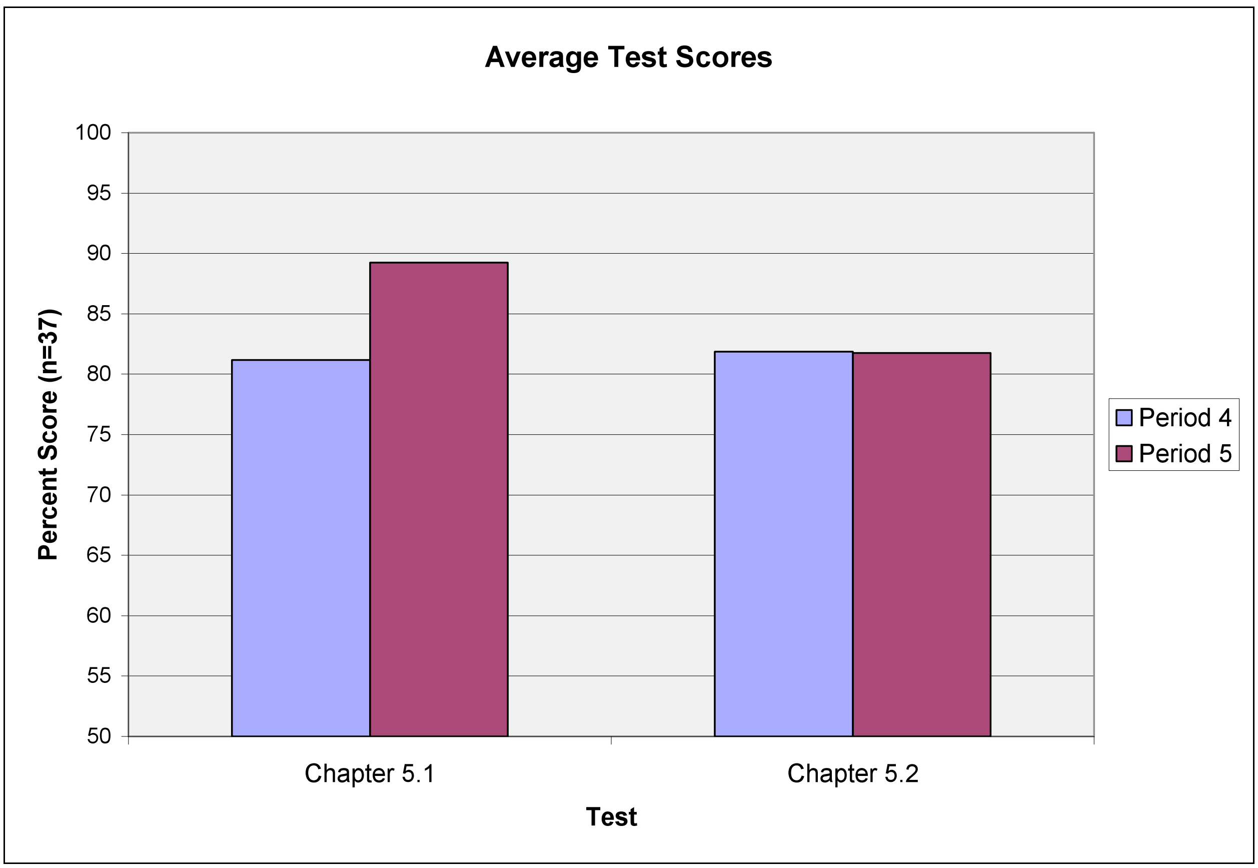

Figure 4. Average test scores for chapter 5.1 and 5.2.

In addition to analyzing quantitative data from tests and quiz scores, I quantified qualitative data that students generated by answering pre and post opened ended questions on a pair of online questionnaires. Students responded to several questions that PhysTec improved many traits associated with achievement in physics. When asked directly about increasing performance on tests, 50.7% of students (n=69) responded that PhysTec does improve their performance. Only 14.5% of students disagreed or strongly disagreed that PhysTec improves their performance on tests (Figure. 5).

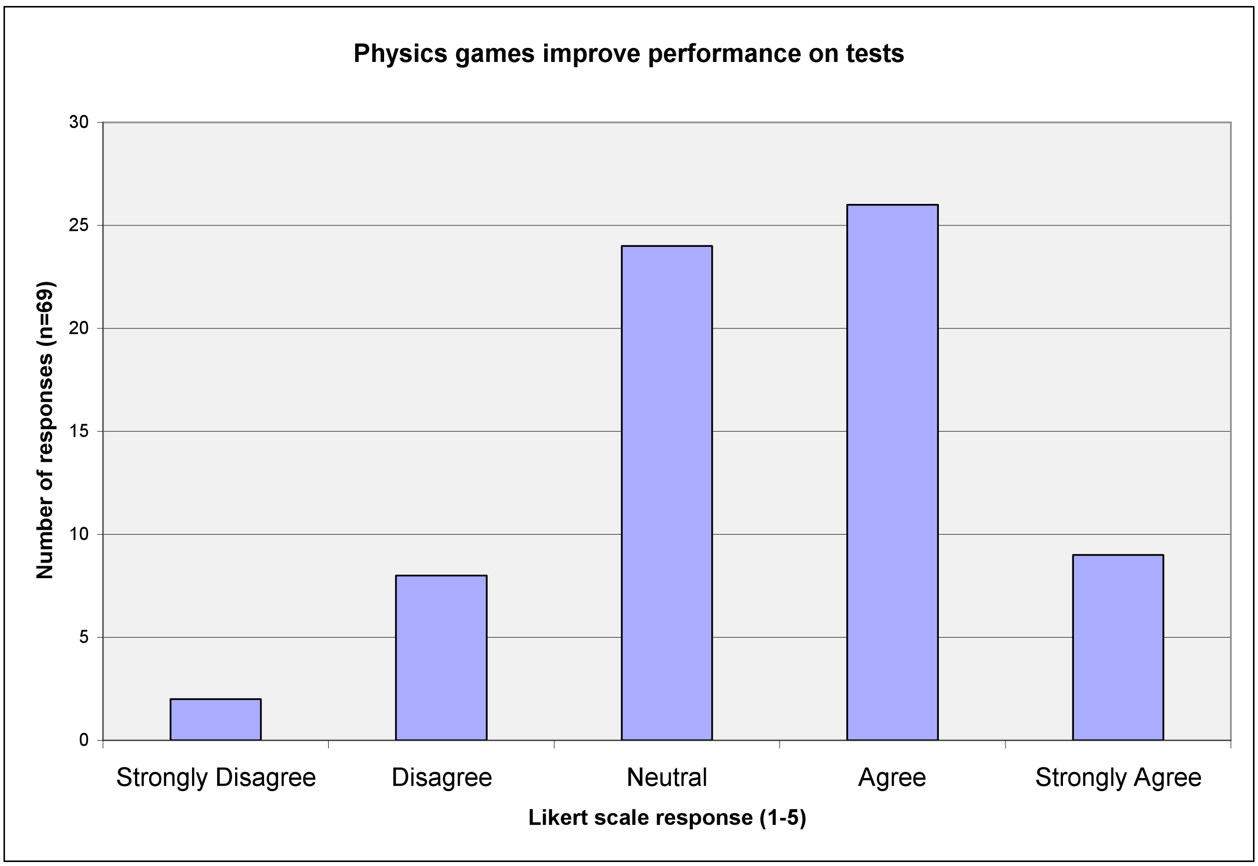

Figure 5. Number of students who believe playing physics games improves test performance.

I also interviewed two students individually, one from each period chosen at random. Both students claimed that the PhysTec game improved their achievement on tests. Here are two excerpts from the interviews:

> *Teacher* – "What effect does the physics game have on your academic achievement?"
>
> *Student A* - "I think it helps me more because you see a lot of the same types of problems show up, like on the homework and on the tests. So, when you're actually working with other people to figure it out and stuff, I feel that I remember it more. And so, I kind of think back to the game and what steps we took to like, solve the problem and everything, to figure out whatever I am working on."
>
> *Student B* - "After doing these games, it made, (pause) it made me, uh, (pause) it made my thinking more expeditious, I guess. So, it was, it was really good because you know, the concept of pressure, it helps you with like study for some kind of, like AP, plus like um, plus how the people would rush to the box, and you would try to get in as fast as you can, but like with the right answer. So it helps you on knowing it, like judgment and everything.…It really helps me on tests a lot.…It was really great practice."

Student Attitudes Toward Physics

In order to analyze the impact PhysTec had on students' attitudes toward physics, I analyzed pre and post Likert scale surveys. First I analyzed initial attitudes toward general academic games played in class. Responses from the survey given before students were exposed to the Phystec demonstrated that students were in favor of playing games in academic classes (Figure 6).

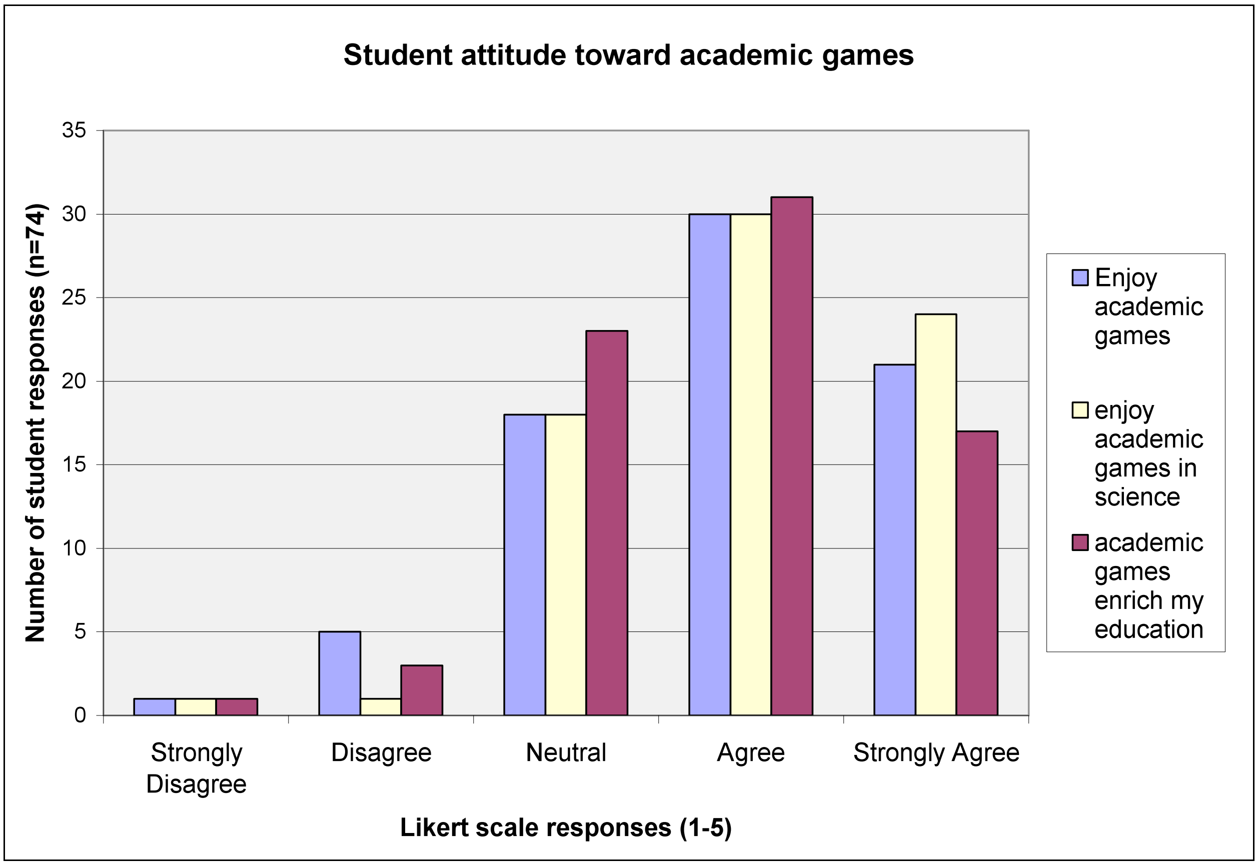

Figure 6. Student attitudes toward games in academic classes.

To investigate the effect PhysTec had on attitude toward physics I analyzed responses about interest and engagement within the class as a result of participating in the PhysTec game. Students showed positive interest in the game, 85% of students (n=68) answered that physics games make the class more fun (Figure 7). Students also responded that the game increased engagement. Similar to responses about general academic games on the pre-survey, students responded on the post-survey that the PhysTec game improved performance in the class .

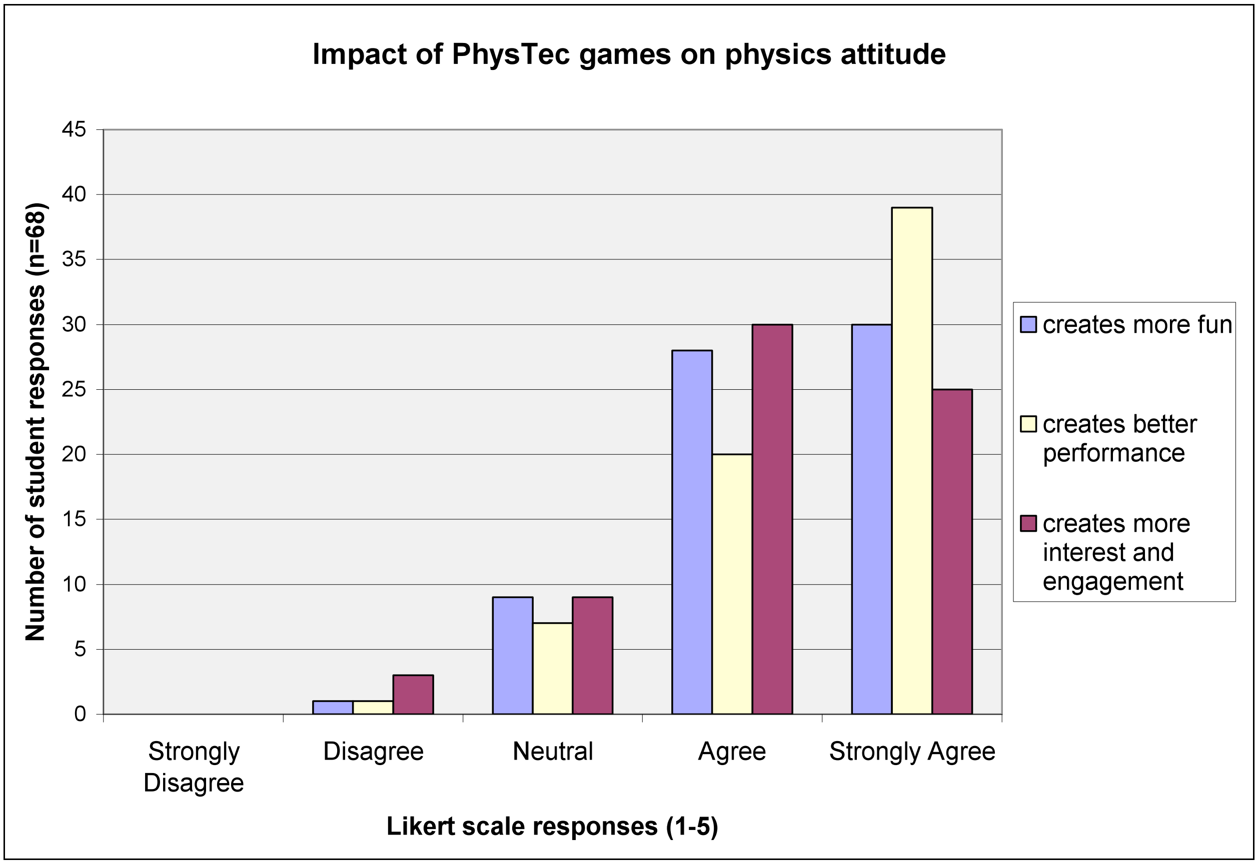

Figure 7. Student response to PhysTec's impact on fun, interest and performance.

In order to ensure questions were not leading students to give desired responses, I analyzed responses to questions asked with negative connotations. Again, students responded strongly in favor of the game as shown in Figure 8. Students did not find the game dull or uninteresting. They did not find that the game would cause them to participate less than normal. The game also did not cause anxiety in the majority of students, although some 26.1% (n=67) did report feelings of anxiety while playing the game.

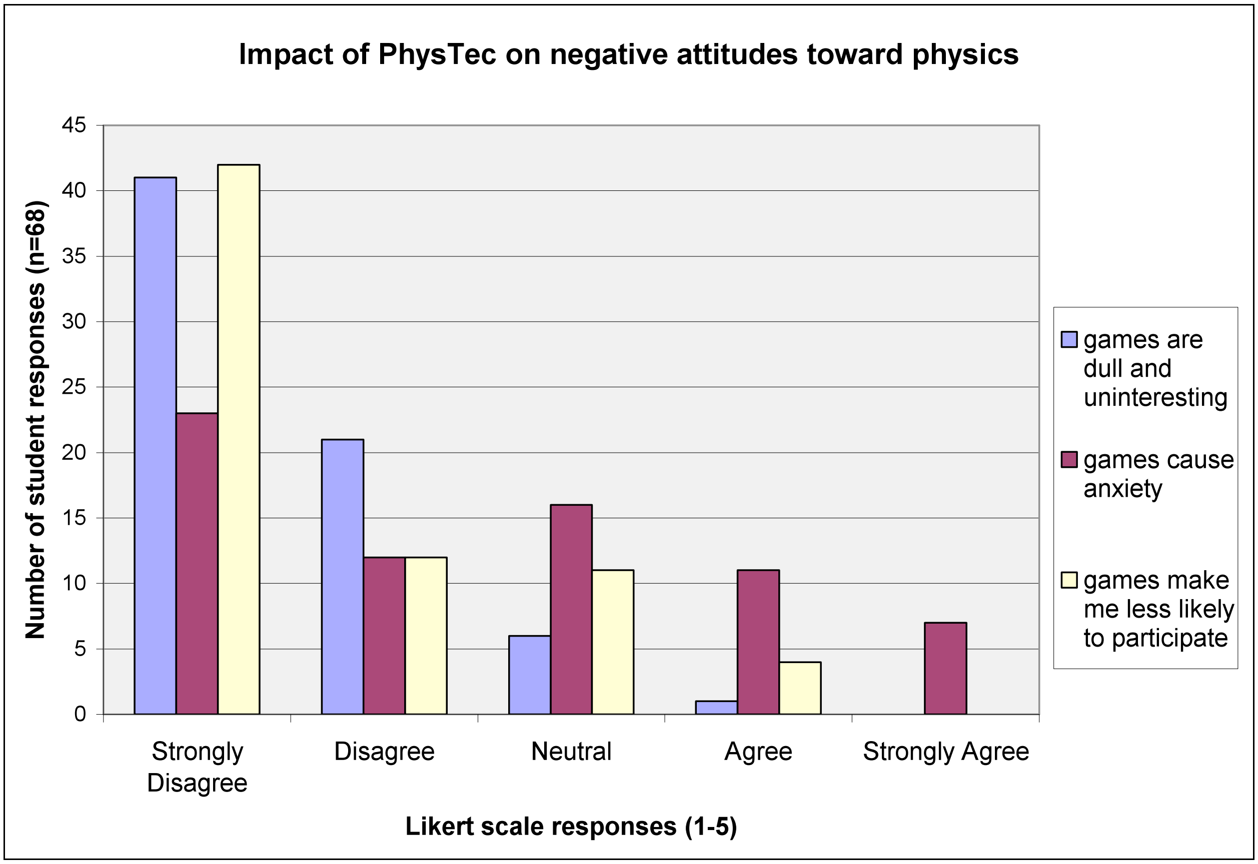

Figure 8. Student response to PhysTec's impact on dullness, anxiety and lack of participation.

Additionally, I asked open ended questions about student affinity toward physics and the PhysTec game in a post game questionnaire. Students responded that the game was enjoyable 76.6% (n=64), and gave a wide array of reasons for liking the game. I coded positive responses as yes, negative responses as no and responses that were unclear as neutral (Figure 9).

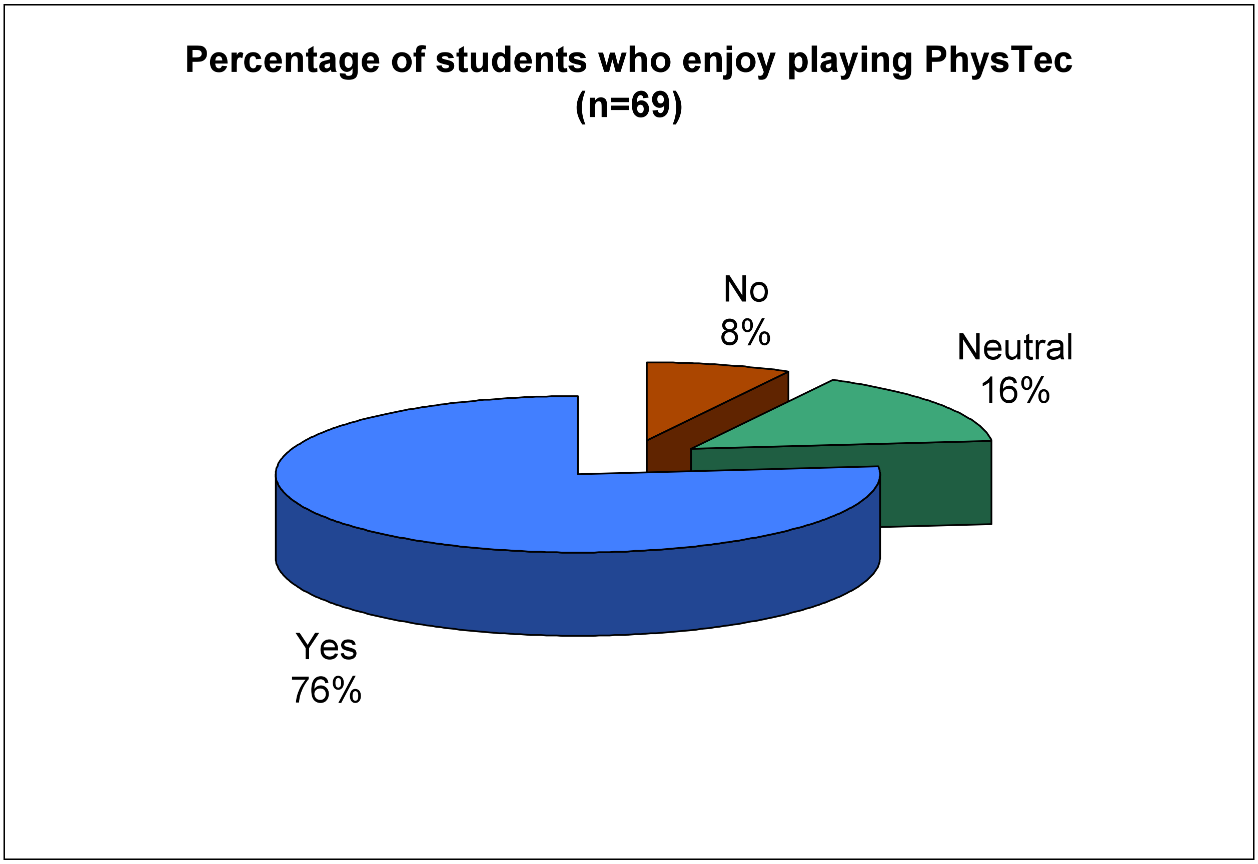

Figure 9. Percentage of students who enjoy playing PhysTec game.

What is even more revealing, is the reasons students gave to justify their answers. Table 1 is a partial list of the some of the reasons for positive and negative responses to the question "did you enjoy playing physics games in this class?".

Table 1. Examples of student responses to questionnaire question on enjoyment of physics games.

Reasons for a positive (yes) response 76.6 percent (n=64)	Reasons for a negative (no) response 7.8 percent (n=64)
• Games are always fun in a class rather than just sitting and learning. There's more interaction. • They help to collaborate on equations that I have problems with and is very engaging. Both these qualities help to further my understanding in class. • I'm a competitive kid. Games are my thing. • They make the class fun and gives me the opportunity to learn from other students. • Because it makes the entire class enthusiastic and lively • It helps me visualize and understand better. • I feel that they help bring together everything that we had learned in a chapter. • Competition and winning is highlight of any day, weather it be in running, art, aca-deca, or physics.	• I like games, but I don't really like the physics game we play. It is stressful, the questions are much harder than most others, and there isn't a forum or sufficient time to explain them • The games give too much pressure to be first rather than just finishing within the time limit and solving the problem carefully • Sometimes it was stressful when I did not know the answer to the question. • I do not think well when given time limits. It imposes undesired stress which distracts me and leads to a wrong answer when I would have otherwise gotten it correct. • No especially. It was good because it taught me to think quickly and in new ways (finding shortcuts). For me, I learn better by going over example problems.

Data from the student survey also revealed that 51% of students (n=69) feel they perform better academically in a class that plays academic games, as shown in Figure 10. I also questioned students on the educational value of PhysTec. Their attitudes toward the value of game play were positive. After playing PhysTec, 72% of students (n=68) felt that the PhysTec games had educational value (Figure 11).

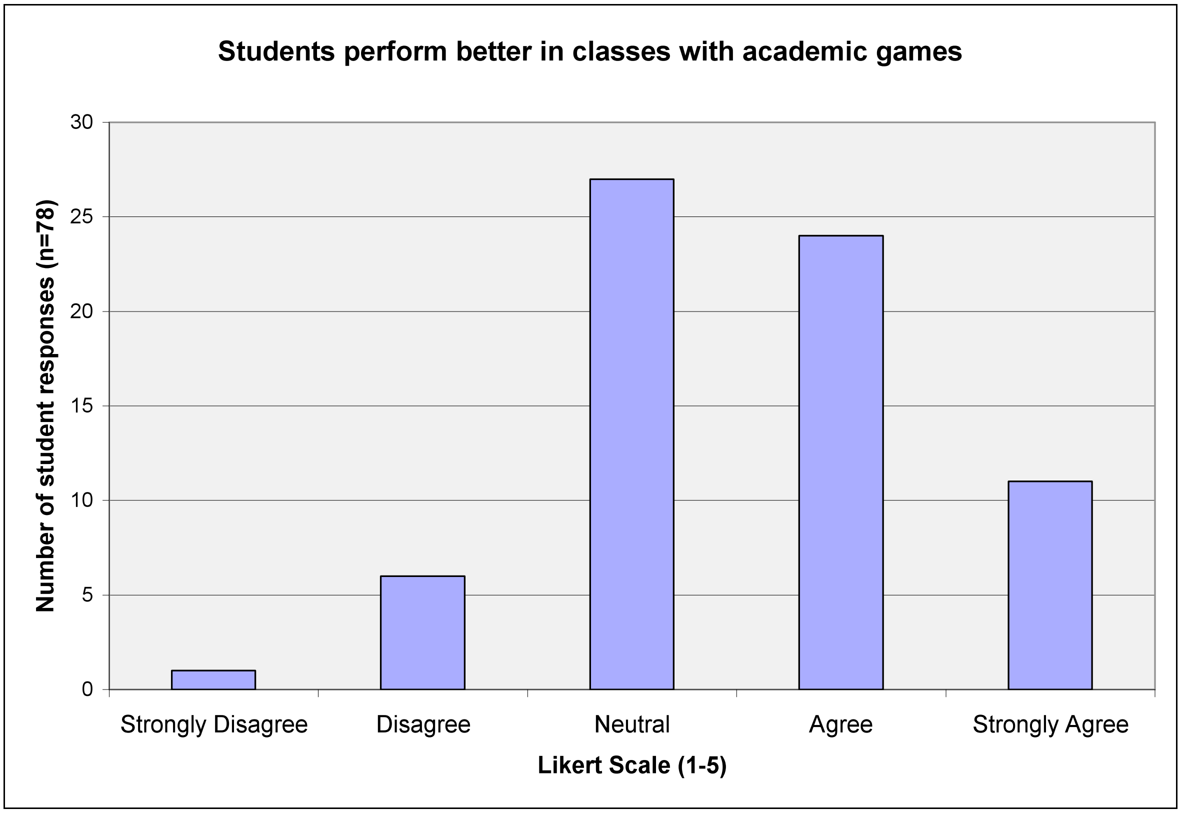

Figure 10. Students who feel performance is enhanced by games.

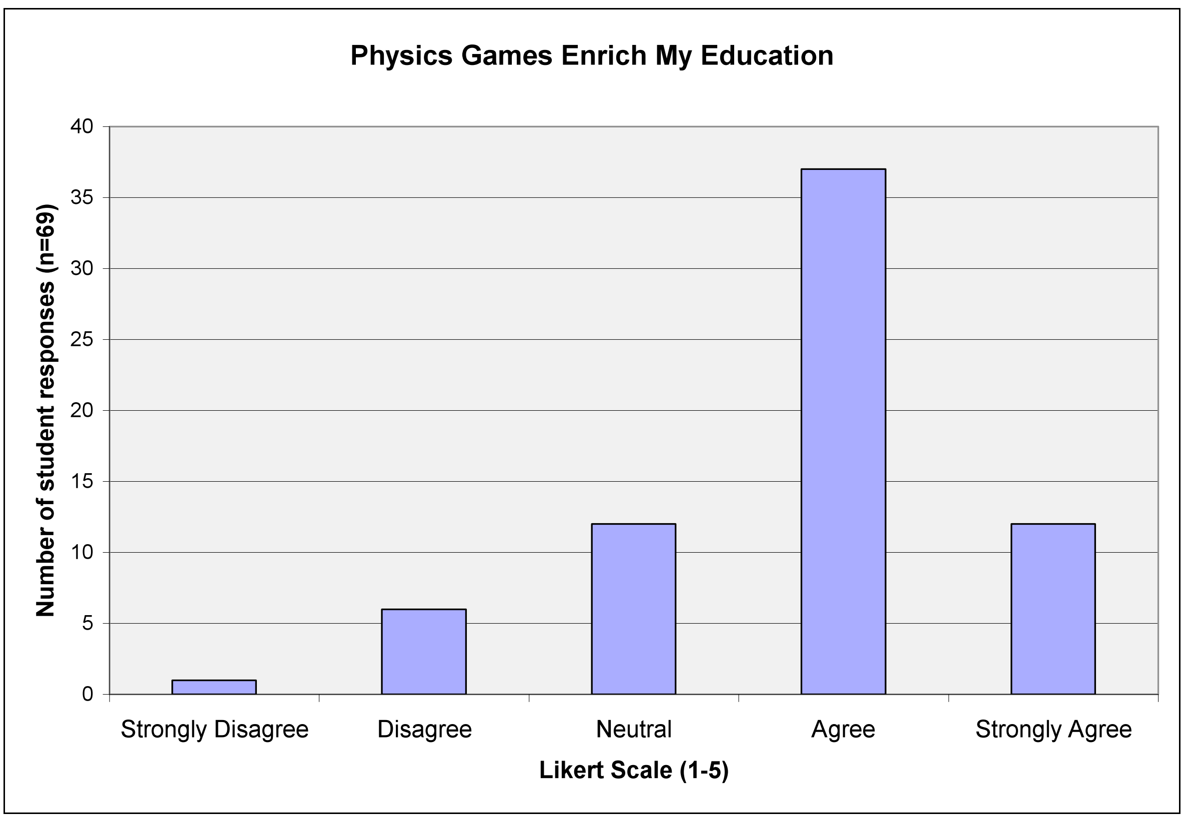

Figure 11. Students who feel physics games enrich education.

Before ever playing the PhysTec game, students had very positive attitudes toward academic games in class. Students felt games had motivational, and educational value. Students also felt using class time for academic games was valuable (Figure 12). On the pre-questionnaire, many students commented on previous games they had played, like Jeopardy based science games, that they really found useful and motivating.

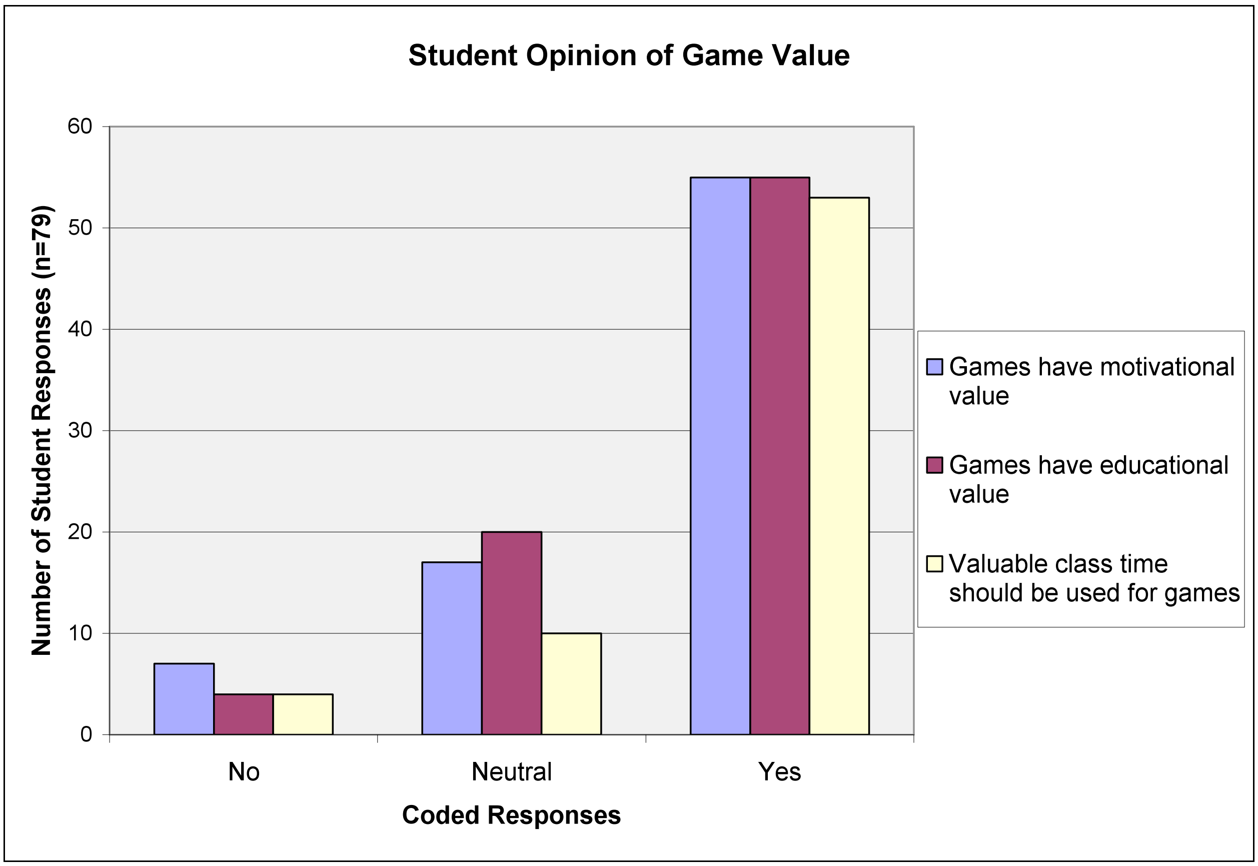

Figure 12. Student opinion on motivational and educational value of game play in class.

After Playing PhysTec, students continued to responded that this particular academic game had value. Figure 13 shows that students felt the game provided motivation for physics. Students also responded that PhysTec contained educational value for physics.

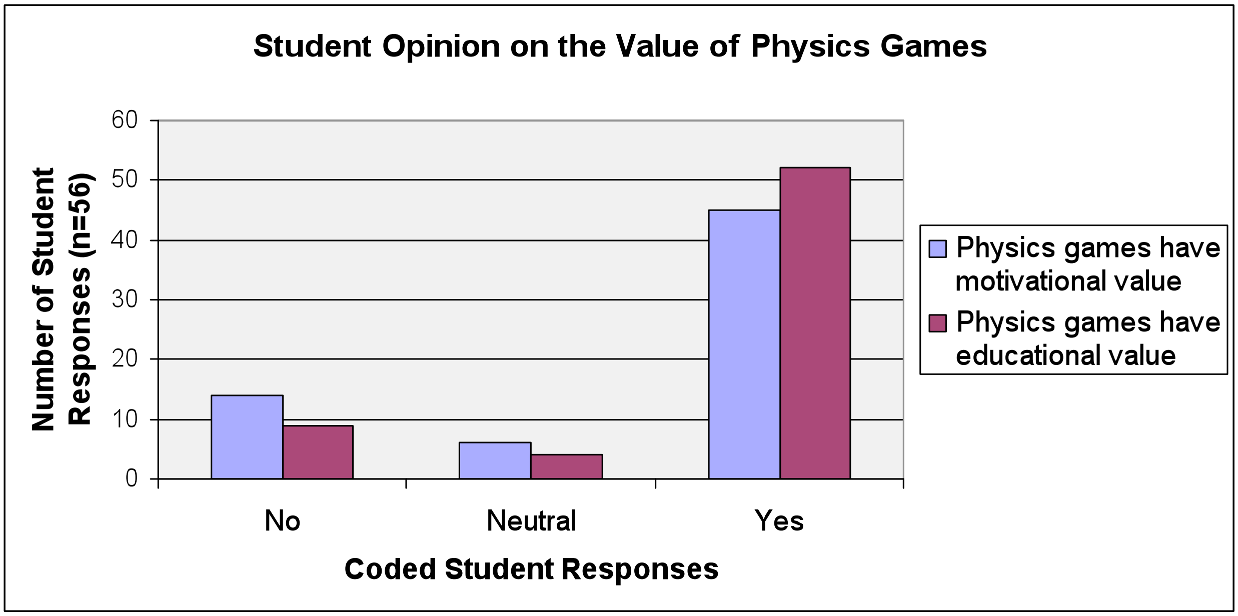

Figure 13. Student opinion on the value of physics games.

In order to analyze whether the game made a difference in overall affinity toward physics, I coded responses to the very direct question, "did playing games in this class change your attitude toward physics?" I differentiated between no effect, no clear answer, having a positive effect on the students attitude and having a negative effect on the students attitude toward physics. 32.2% of students (n=65) responded that the game did change their attitude of physics in a positive way. 55.4% of students responded that there was no change in their opinion. So, playing PhysTec increased affinity.

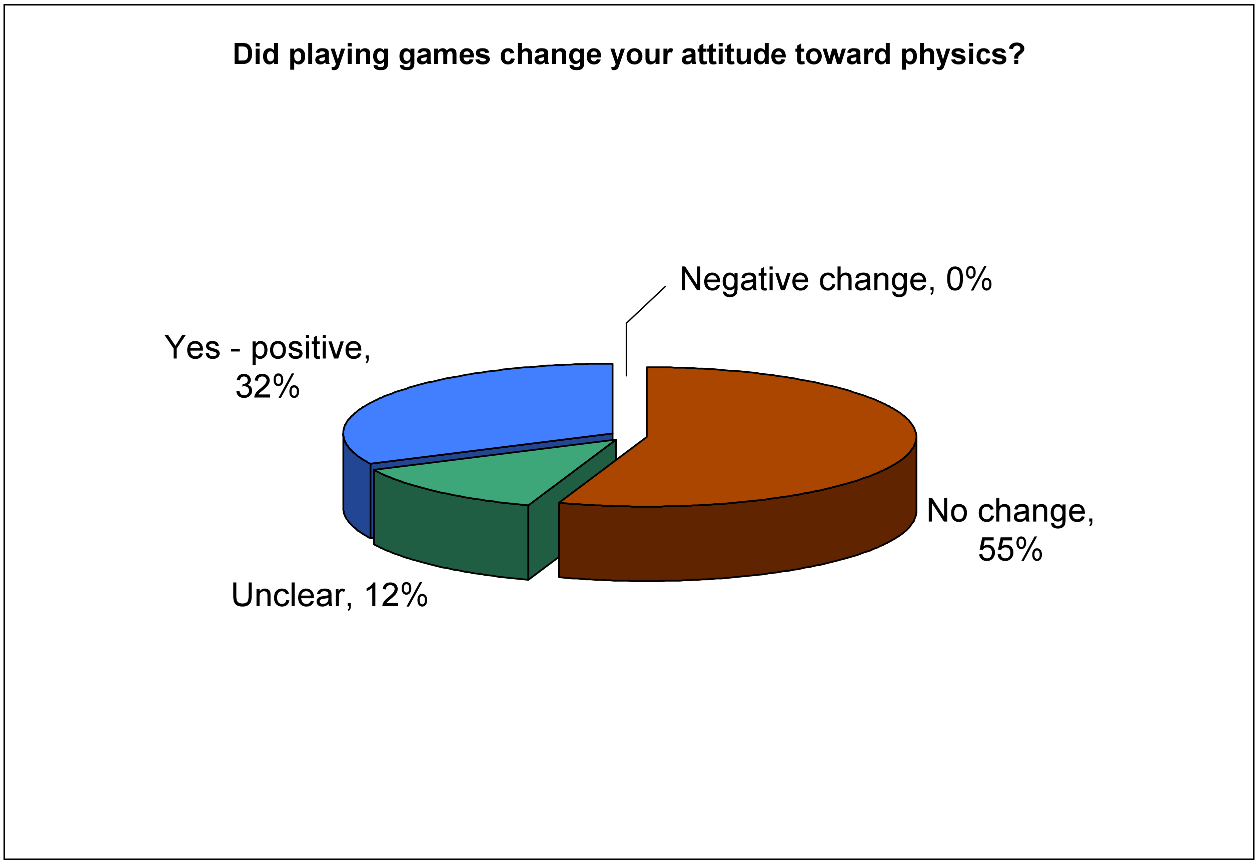

Figure 14. Students who attitude towards phyics changed due to PhysTec game.

No students reported a negative change in attitude toward physics from the game. Table 2 is a sample of the reasons students gave for changes or lack of changes in attitude.

Table 2. Examples of student responses to questionnaire question on a changed attitude toward physics after playing physics games.

Reasons for a positive (yes) response 32.2 percent (n=65)	Reasons for a negative (no) response 55.4 percent (n=65)
• The games made the class much more fun and interesting, and they encouraged teamwork and cooperation. • It make the class interesting and fun. If it wasn't fun I would not be encouraged to do well in it. • I began looking forward to physics more then my other classes. It is something that students can interact with and it isn't boring like hearing the teacher talk/lecture the entire period. • It has helped me visualize the problems better. • It made me a little more excited about physics, because I was directly applying it. • It added a new dimension to my viewpoint of Physics. I am more excited in the learning realm of Physics C. • It made it more fun and interesting to talk about ways to solve different problems with your fellow classmates. • It was more fun and engaging than bookwork. working as a team also helped educationally • I think Physics can become rather monotonous when it consists merely of math problems. The games change things up and makes things more exciting; I definitely learn better when the subject is interesting and exciting.	• No, while the games are interesting and engaging, my opinion on the class remained the same. • The "physics games" didn't really change my attitude toward the class, but sometimes did provide the understanding of the real-life applications of the formulas (aka the AHA moment). • The games just made me realize that I need to practice doing questions with speed. They didn't make me like or dislike physics any more or less. • I already liked this class from the beginning. • It is a good way to review the material, but it did not change my attitude in any way. • Playing games makes the class more fun, but overall, I still feel the same way about physics • The games just made some of the concepts easier to understand. • My attitude toward the subject was already positive • Since the start, I have always viewed physics as a fun and demanding challenge. • Did not change my attitude about physics. My attitude about physics, specifically with per. 4 Holloway, is that it has been an enjoyable class; the games only strengthened these feelings.

One student summarized their experience this way,

> "Competitive group-work is what makes physics class stand out from my other 6 periods. Other classes have group work but generally no timed competition. When you add the clock, teamwork's importance is elevated to a new level. You see people specializing as calculator workers, explainers, double-checkers, the hapless writers, and (sometimes) the One that misleads the whole group. When the whiteboard moves around, the dynamic constantly changes. When your friends are counting on you, that's a powerful motivation to study. Physics is not a math class; it's a puzzle class."

I also conducted interviews with two students selected at random, one from each period, to ascertain their view of changes the game made to their academic achievement in the class and their affinity for physics. Both students reported that the game improved their academic performance. Both students claimed that they liked physics more after playing the game. Both students felt that PhysTec brought many positive aspects to the class including collaboration, competition, practice, peer teaching and having fun.

> *Student A* – "I think it (PhysTec) helps a lot 'cause it actually gets people motivated to work with it and learn the stuff and work together…. Me personally, I like working with other people, if you need to teach someone else or someone else is teaching you, I feel like I remember it more…. It (PhysTec) makes me like it (physics) more, because you don't have to really take it that seriously, but …even if it is a fun competition, you feel like you get more involved in it and start enjoying it a lot more and wanna do it since it's fun."

> *Student B* – “I think that the physics games were helpful. It’s like it gives you a little bit of competition, so like there’s a time pressure, and you can collaborate with other students and that was really good, so it’s useful…. The game made me like physics more, but not as like, not as much as like if there were real world applications….”

To summarize, PhysTec improved student affinity toward physics, increased engagement and motivation, and increased the level of fun students had in class. Students responded that PhysTec made physics more interesting, helped improve their performance on homework and tests, and increased their participation. The only negative aspect found in the data on attitude was a mild level of anxiety experienced by some students. The anxiety appears to be mild enough not to decrease affinity toward PhysTec or physics, as no students responded to liking physics less after playing the game.

Discussion

Academic Achievement

In analyzing the data in an attempt to determine the impact of PhysTec on student achievement I noticed several different results. The data from the chapter tests showing academic achievement was mixed. Some quantitative data I collected suggested that the game decreased academic achievement while other data points showed increases in academic achievement. The trend in academic achievement over time is inconclusive as shown in Figure 1. This apparent lack of a singular trend is due, I believe, to the chapter tests being unequal in difficultly. As the physics course progresses, the concepts become more complex and abstract. It is interesting to note however, that even though the trend in chapter test scores showed both losses and gains in achievement, as the course progressed, both classes maintained relatively high average scores, over 80%, with the only drop below 80% occurring on the chapter four test. As figure 15 shows, there is a statistically significant increase ($p<.05$) in average test scores from both periods from the chapter four test to the chapter 5.1 test and from the chapter four test to the

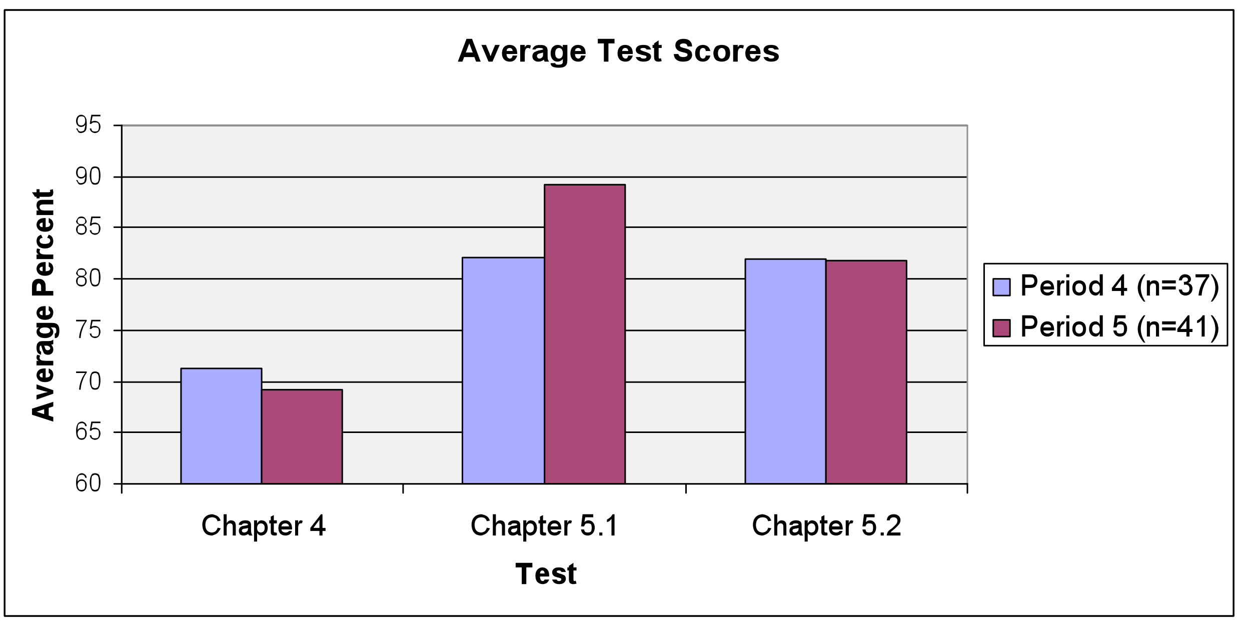

Figure 15. Increases in test scores from chapter 4 to chapter 5.2.

chapter 5.2 test. This increase may be due to game play which increases student discussion and helps students understand how to better process abstract ideas, or simply having more time to absorb the ideas and internalize their meanings may have caused the increase in test scores. The test scores went up between the chapter four test and the chapter 5.1 test even though the students had not played the game designed to cover topics in chapter five. This leads me to believe the game cannot be solely responsible for the increase, but another unknown factor is at work here. Since the trend in scores, from beginning to end, remained relatively high, I believe the use of the game did not lead to an overall drop in achievement. Although results in achievement are mixed, there are two strong cases for an increase in achievement: the increase in quiz scores and the increase in test scores from chapter four to the end of chapter five. My impression of the game's benefit on achievement comes mostly from student comments made to me after playing the game. They would routinely ask when was the next time they would get to play. Some students said directly that it helped them on tests. One student responded on a questionnaire this way, "I think playing games in physics has somewhat helped me educationally. It helped make me more aware of my weaknesses before tests. Also, I think that timed games help train students to think faster." It was positive comments like this that suggested the game makes for an excellent review tool before tests. This was one of my main motives in designing the game. I wanted to be able to use the game as test review to foster achievement as well as improve attitude.

With the exception of the chapter four test results, the game appears to work well as a test review. Again, I believe drop in achievement on the chapter four test is due to the sharp rise in abstract concepts covered on that test. In the future I hope to more thoroughly compare academic improvement. I would like to conduct this study again or a similar study using a pre and post test for each chapter. The pre and post test would ask questions based on the same concepts at similar difficulty levels.

In order to further investigate the impact of competitive collaborative game play on achievement, I attempted to use period five as a control group, unfortunately, after hearing from period four how fun the game was, they demanded to play the next session. During the first round of treatment, the test scores for both the treatment group, period four, and the control group, period five, dropped between the chapter two test on linear motion and the chapter three test on two dimensional motion. Period four dropped more (6.3%) than period five did (3.4%) and period four's drop was statistically significant ($p<.05$) whereas period five's was not. Still, the fact that both classes dropped suggests two things: first, the two tests may have been too different to show trends in achievement and secondly, that PhysTec may not have been responsible for the drop. In the past, the chapter three test was where students start to struggle with physics because the ideas begin to get very abstract. Students have a hard time accepting the concept that what happens to an object in one direction has no consequence to how it moves in a perpendicular direction. It is for this reason that I believe the chapter two test and the chapter three test are not closely enough related to be considered a good pre- and post-assessment of student knowledge. Since the tests are not equal in difficulty and do not cover the same subject matter, only limited conclusions can be drawn from this data. It is possible that the PhysTec game caused students to perform worse academically as period four did, but I believe that the drop in test scores is more attributed to the increased difficulty of the test. When looked at in isolation, the second set of chapter tests, chapter 5.1 and chapter 5.2, also had similar results. This time, period five, now also receiving treatment, had a statistically significant drop, 7.5%, and period four did not (Figure 16). For this round of chapter tests, both periods had been exposed to the PhysTec game on at least two separate occasions. Like the previous chapter tests, I do not think that these two tests were good assessments for tracking trends in achievement due to the PhysTec game. The test for chapter 5.1 covers introductory ideas involving work and energy, but the chapter 5.2 test involves more complex and abstract applications of work and energy. The increased difficulty alone could be the reason for the decrease. The other consideration is the average on the first test was unusually high for period 5 (89.2%). The average for the second test was a more typical average (81.7%), near the same average that period four ended up with on the second test (81.9%). Both averages suggest that most students

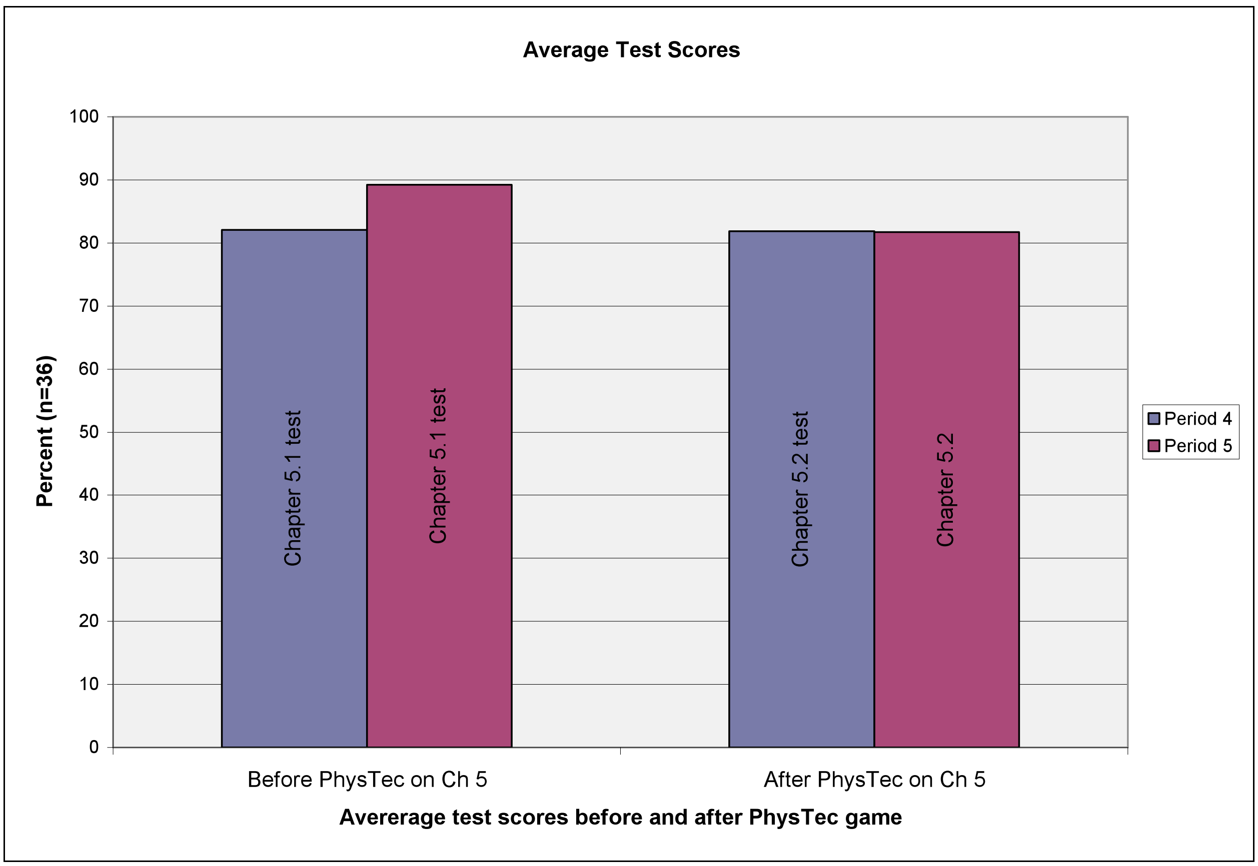

Figure 16. Changes in test scores after playing PhysTec.

are being successful and mastering a majority of the information. When looking at the overall averages, the students were successful on all tests with the class averages at or above 80%. Again, this suggests that PhysTec does not interfere with success, but it is not conclusive that PhysTec increases achievement in chapter tests.

My other quantitative assessment, the pre- and post- quiz for chapter four, showed significant gains for both classes and was the best representation of quantitative improvement in student test scores. Both periods were exposed to the PhysTec game in between the pre- and post- assessment and both made significant gains in average scores (Figure 3). This suggests that the game does improve academic achievement. The quizzes were similar both in the content and in difficulty, creating an excellent pre/post comparison on student achievement.

Qualitatively, the data suggests that the students felt the game greatly improved their academic achievement. Student responses in several areas, including the surveys, questionnaires and interviews, demonstrate that students felt the game helped improve academic performance in the class. The fact that a vast majority of students, 80% (n=65), felt that the PhysTec game had educational value (Figure. 13), suggests that the game should be included as a regular part of the physics class. Anytime students can see value in an educational tool, then it is being effective and its use should be continued. I plan on creating a greater number of PhysTec games to cover the entire year.

Additionally, 64% of students (n=75) felt that academic games enrich their education (Figure 11) and finally, both students who were interviewed agreed that PhysTec improved their academic performance in the class. This is important because it suggests that this style of game could have similar effects in other science or other academic classes as well. Since the game potentially had some undesirable aspects, such as anxiety and lack of extensive time to go over solutions, I expected more negative results. The lack of strong negative opinion suggests that these weaknesses are acceptable as part of the construct of the game. All of these qualitative indicators suggest that academic achievement is improved by playing the physics game. One student said it this way,

> "I think it (PhysTec) helps me more because you see a lot of the same types of problems show up, like, on the homework and on the test. So, when you're actually like, working with other people to figure it out and stuff, I feel like I remember it more. And so, I kind a just think back to the game and what steps we took to like solve the problem, and everything, to figure out whatever problem I'm working on."

When this qualitative data and the pre and post quiz data is taken together, I feel that students' academic achievement in physics is enhanced by participation in the PhysTec game.

Student Attitudes Toward Physics

In analyzing the data in an attempt to determine the impact of PhysTec on student attitudes toward physics I noticed several different results. Students reported increased affinity, and increased motivation toward physics. They reported feelings of increased interest and engagement, increased fun and better test performance. They also reported that PhysTec had educational values and this style of academic game is worthy of valuable class time. Overall, student attitudes toward PhysTec were very positive. With some students, that positive attitude was transferred to their attitude towards physics.

The qualitative data for physics affinity suggests that a portion of students did develop an increase in affinity toward both the PhysTec game and physics in general. Even though the data suggested that by playing the PhyTec game some students' affinity toward physics increased, many reported that they retained the same affinity for physics as before playing the game. I believe this is due to the type of student that takes an AP level science course. Usually, the students in an AP class enjoy science and have experienced previous success, and so, come in to my class with a relatively high affinity to begin with. It is then difficult to increase upon this high level of affinity. PhysTec did support and maintain that high level of affinity. Several students reported that they already liked physics and that the game reinforced their affinity for physics, but that it did not increase it. Maintenance of a high level of affinity is a positive outcome and should be considered a success. It would be interesting to test PhysTec or a similar game on group of students who do not profess an affinity toward science. I believe the game would have a greater impact on students who have not already found an affinity for science.

Some students mentioned that they liked the game, but they experienced a level of stress during the game which was uncomfortable. These students did not report liking physics less, but that they would like to see a less stressful game being played. I would like to continue to study how the game could be made less stressful, thereby reducing anxiety in some students. Part of the design of the PhysTec game was to expose students to stressful conditions through competition. The students will feel a great deal of anxiety at the end of the course as they take the AP exam and exposing students to small anxieties during the year may provide familiarity and make the AP exam anxiety less debilitating. One very positive conclusion I drew from the data was that no one showed a decrease in affinity toward physics. This leads me to believe there is loss in affinity when using the PhysTec game in class.

A large majority of students responded that the game had many beneficial attributes, including: motivational value, made physics more fun and made the class more interesting and engaging (Figure 7). Motivation, fun, interest and engagement are all characteristics of affinity. Again, the majority students responded that these characteristics were present which suggests a strong affinity toward the game and physics in general. These positive descriptions suggest that students thought better of the class and of physics, due to participation in the game. When the students were asked directly if the game changed their attitude toward physics in a positive way, 32% (n=65) responded that it did (Figure 14). A third of my students now think more positively about physics after playing competitive collaborative physics games in class.

What was as important was that 55% of students surveyed (n=65) said there was no change in their opinion of physics. Many students, who listed that they did not like physics more, described it like this, "playing games makes the class more fun, but overall, I still feel the same way about physics." Since no one claimed that they liked physics less after playing the game, there appears to be no data to suggest the game reduces affinity. This implies that PhysTec not only worked at creating greater affinity for physics, but that the game should be used with greater frequency. I predict that additional use of PhysTec would greatly aid students further. The last month before the AP exam in May is typically filled with review, primarily in the form of practice tests. Students soon begin to complain of the stress and tedium of the repeated tasks. The interjection of the PhysTec game could greatly reduce boredom, improve collaboration and still adequately review material in a timely manner. I would like to further research the use of PhysTec as an end of year review tool.

Further implications of this study are that teachers can include competitive collaborative game play into lessons and maintain a positive educational outcome while improving affinity toward the subject matter. Games not only improve affinity, but may also lead to greater academic achievement. Educators should also embrace the use of competition within the classroom as a means of motivating students, especially when used with collaborative teams. This study also provides a foundation for designing academic games that may be used in other curricular areas.

Research limitations and recommendations for future research.

The largest limitation to this study is the design of the pre- and post- chapter tests. The tests were not measuring the student understanding of the exact same topics pre and post exposure to the games. I would like to repeat this study with new pre- and post- tests that fairly compare what students know before and after the treatment. The poor design of the pre- and post- chapter tests make gains or losses in achievement difficult to determine. This study appears to apply positively to Advanced Placement physics students who enjoy challenging classes. Westlake High School is in an affluent suburban area and has a great deal of competition as many students take AP classes and apply to top colleges around the country. These results I found may not reflect the results that would occur at a highly urban or low socioeconomic high school. AP students are also highly motivated. I would like to expand my study to see less motivated students, like my college prep physics students or regular biology students, would also respond favorably to the game. I would also like to expand the study to include other AP science classes including AP biology, AP chemistry, and AP environmental science. The game questions could be changed easily while maintaining the key components of the game, competition and collaboration. My sample size was also too small to make truly profound conclusions about the effectiveness of the game on achievement and attitude. I would like to expand the study to include the other two high schools in the district or possibly in another district with a vastly different demographic of students. This would also provide evidence if the game could be used by a variety of teachers with the same effect. Finally, I would like to see if the positive results in achievement and in attitude could be expanded by tweaking some of PhysTec parameters, such as how points are earned, which may reduce stress.

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Appendix

Appendix A. Survey form before treatment.

Academic Games (Before)

This form should be filled out before playing any academic games in Mr. Holloway's class. All questions refer to any games played in any academic class you have taken.

* Required

Last Name *

First Name *

Period *

Period 2

I enjoy playing academic games

3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I enjoy playing academic games in science class

3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

academic games enrich my education

3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

academic games help my performance on tests

3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

academic games cause me great anxiety
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I really enjoy academic games that are very competitive
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

academic games are a waste of class time
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

academic games cause too much disruption
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

although fun, academic games have no education benefit
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

although educational, academic games are dull and uninteresting
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I would like to have more academic games played during class
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Academic games make a class more fun
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Academic games make a class more interesting and engaging
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I perform better academically in a class that is interesting and fun
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I perform better academically in a class that plays academic games
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Submit

Appendix B. Student questionnaire before treatment.

Physics Games - Student Questionnaire #1

Please complete the entire questionnaire to the best of your ability providing honest and detailed answers. All responses are for research information only and will not affect your standing in this class. After data is compiled your name will not be attached to any data that is published. Thank you for participating

* Required

Name (Last, First) *

Period

Period 4

What is your favorite subject and why?

Try to list reasons why you like one subject the best. Be specific.

Why did you take AP physics?

Try to give a detailed response please.

What do you currently plan on pursuing in college (major and degree)? (If undecided, tell me which field(s) you are considering).

What influence your choice of college major?

List/discuss all major influences in order of importance.

How much influence do high school classes have on your choice of major?

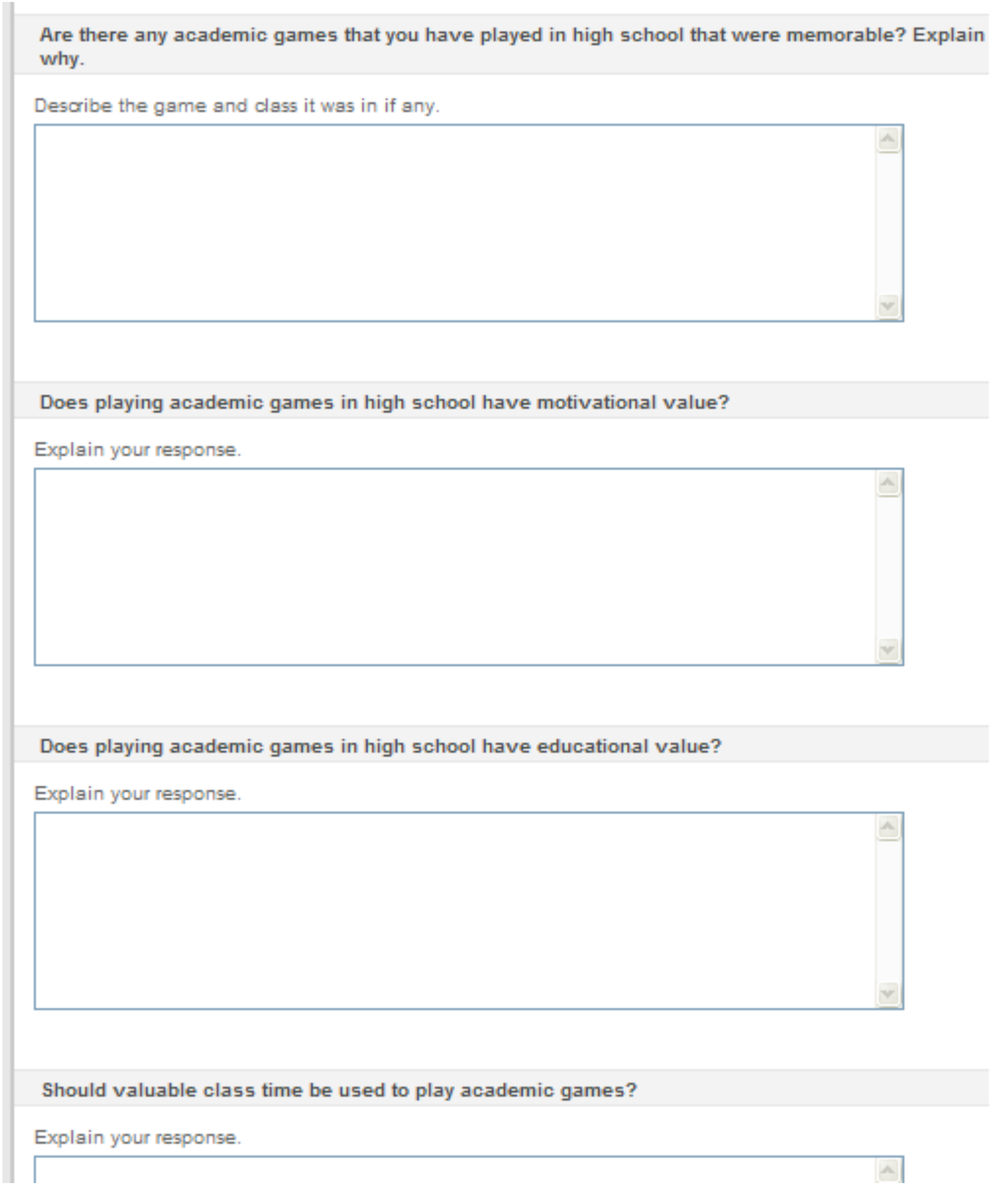
Explain the impact (both positive and negative) on your choice of what you pursue after high school.

What factors cause a class to have a positive influence on your choice of major?

Give an example if you can.

What factors cause a class to have a negative influence on your choice of major?

List all that you can think of.



Are there any academic games that you have played in high school that were memorable? Explain why.

Describe the game and class it was in if any.

Does playing academic games in high school have motivational value?

Explain your response.

Does playing academic games in high school have educational value?

Explain your response.

Should valuable class time be used to play academic games?

Explain your response.

Should valuable class time be used to play academic games?

Explain your response.

Do academic games played as a team have any value?

Explain your response.

Submit

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Appendix C. Student survey after treatment.

Physics Games (After)

This form should be filled out after playing one or more physics games in Mr. Holloway's AP physics C class.

* Required

Last Name *

First Name *

Period

- Period 2
- Period 3
- Period 4
- Period 5
- Period 6
- Period 7

I enjoy playing physics games
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

physics games enrich my education
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

physics games enhance my performance on tests
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

physics games cause me anxiety
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

physics games make me less likely to participate
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I enjoy highly competitive academic games
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

physics games are a waste of valuable class time
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

physics games are too disruptive
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

although fun, physics games offer no educational benefit
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

although educational, physics games are dull and uniteresting
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I would like to play more academic games during class
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

physics games make physics class more fun
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

physics games make physics class more interesting and engaging
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I perform better academically in a class that is interesting and fun
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I perform better academically in a class that plays academic games
3 is neutral or no opinion

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Submit

Appendix D. Student questionnaire after treatment.

Physics Games - Student Questionnaire #2 (After)

Please give honest answers including the reasons why you feel the way you do. If you can relate an example that fits, please do.

* Required

Name (Last, First) *

Period *

Period 4

Did playing games in this class change your attitude toward physics

Please give a complete answer, not just yes or no. Explain why.

Has your choice of major changed since the last questionnaire? Explain why.

Did this class, AP physics C, have an impact on your choice of major? How?

Do you consider AP physics C more or less interesting than other classes? Why?

Do you enjoy playing physics games in this class?

Does playing games in physics have motivational value? (Make you more engaged in the class or subject matter).

Does playing games in physics have any educational value? (You learn more and are able to perform better on assessments).

Submit

Appendix E. Sample questions from the chapter three test

Name: ______________________ **Class:** _________________ **Date:** _________ **ID: A**

AP physics C - Test chapter 3 Two dimensional motion

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Find the resultant of the following two vectors: *i*) 50 units due east and *ii*) 100 units 30° north of west.
  a. 100 units 30° north of west
  b. 62 units 15° north of west
  c. 87 units 60° north of west
  d. 62 units 54° north of west
  e. 56 units 25° north of west

____ 2. Arvin the Ant is on a picnic table. He travels 30 cm eastward, then 25 cm northward, and finally 15 cm westward. What is the magnitude of Arvin's net displacement?
  a. 70 cm
  b. 57 cm
  c. 52 cm
  d. 29 cm
  e. 18 cm

____ 3. I walk six miles in a straight line in a direction north of east, and I end up two miles east and several miles north. How many degrees north of east have I walked?
  a. 19°
  b. 45°
  c. 60°
  d. 71°
  e. 82°

____ 4. A jogger runs halfway around a circular path with a radius of 60 m. What, respectively, are the magnitude of the displacement and the distance jogged?
  a. 60 m, 188 m
  b. 120 m, 188 m
  c. 0 m, 377 m
  d. 120 m, 377 m
  e. 60 m, 377 m

____ 5. John throws a baseball from the outfield from shoulder height, at an initial velocity of 29.4 m/s at an initial angle of 30.0° with respect to the horizontal. The ball is in its trajectory for a total interval of 3.00 s before the third baseman catches it at an equal shoulder-height level. (Assume air resistance negligible.) What is the ball's horizontal displacement?
  a. 76.4 m
  b. 38.2 m
  c. 57.3 m
  d. 66.7 m
  e. zero

Appendix F. Sample questions from the chapter four test.

Name: ______________________ **Class:** _________________ **Date:** _________ **ID: A**

AP physics C - Test chapter 4 Newton's Laws of Motion

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. If we know an object is moving at constant velocity, we may assume:
a. the net force acting on the object is zero.
b. there are no forces acting on the object.
c. the object is accelerating.
d. the object is losing mass.
e. the net force acting on the object isn't zero.

____ 2. An astronaut applies a force of 500 N to an asteroid, and it accelerates at 7.00 m/s^2. What is the asteroid's mass?
a. 71 kg
b. 135 kg
c. 441 kg
d. 3 500 kg
e. 3 600 kg

____ 3. Two forces act on a 6.00-kg object. One of the forces is 10.0 N. If the object accelerates at 2.00 m/s^2, what is the greatest possible magnitude of the other force?
a. 1.0 N
b. 2.0 N
c. 22.0 N
d. 34.0 N
e. 41.0 N

____ 4. The acceleration due to gravity on the Moon's surface is one-sixth that on Earth. An astronaut's life support backpack weighs 300 lbs on Earth. What does it weigh on the Moon?
a. 1 800 lb
b. 300 lb
c. 135 lb
d. 50 lb
e. 40 lb

____ 5. A 2 000-kg sailboat experiences an eastward force of 3 000 N by the ocean tide and a wind force against its sails with magnitude of 6 000 N directed toward the northwest (45° N of W). What is the magnitude of the resultant acceleration?
a. 2.2 m/s^2
b. 2.1 m/s^2
c. 1.5 m/s^2
d. 3.0 m/s^2
e. 1.2 m/s^2

____ 6. Rita accelerates a 0.40-kg ball from rest to 9.0 m/s during the 0.15 s in which her foot is in contact with the ball. What average force does she apply to the ball during the kick?
a. 48 N
b. 72 N
c. 24 N
d. 60 N
e. 76 N

Appendix G. Sample questions from the chapter 5.1 test.

Name: ____________________ **Class:** ________________ **Date:** ________ **ID: A**

AP physics C - Test chapter 5 Work and Energy (Part I)

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Rupel pushes a box 5.00 m by applying a 25.0-N horizontal force. What work does she do?
a. 10.0 J
b. 25.0 J
c. 125 J
d. 550 J
e. 750 J

____ 2. A worker pushes a wheelbarrow with a force of 40 N over a level distance of 6.0 m. If a frictional force of 24 N acts on the wheelbarrow in a direction opposite to that of the worker, what net work is done on the wheelbarrow?
a. 240 J
b. 216 J
c. 144 J
d. 96 J
e. 75 J

____ 3. A horizontal force of 100 N is applied to move a 45-kg cart across a 9.0-m level surface. What work is done by the 100-N force?
a. 405 J
b. 500 J
c. 900 J
d. 4 500 J
e. 5600 J

____ 4. I use a rope 2.00 m long to swing a 10.0-kg weight around my head. The tension in the rope is 20.0 N. In half a revolution how much work is done by the rope on the weight?
a. 40.0 J
b. 126 J
c. 251 J
d. 0
e. None of the above.

____ 5. The work done by static friction can be:
a. positive.
b. negative.
c. zero.
d. nonnegative.
e. Any of the above.

____ 6. A satellite is held in orbit by a 2 000-N gravitational force. Each time the satellite completes an orbit of circumference 80 000 km, the work done on it by gravity is:
a. 1.6×10^{8} J.
b. 1.6×10^{11} J.
c. 6.4×10^{11} J.
d. 0.
e. None of the above.

Appendix H. Sample questions from the chapter 5.2 test.

Name: ____________________ Class: ________________ Date: ________ ID: A

Test Chapter 5 (part II) Work and Energy

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. A worker pushes a wheelbarrow with a force of 40 N over a level distance of 6.0 m. If a frictional force of 24 N acts on the wheelbarrow in a direction opposite to that of the worker, what net work is done on the wheelbarrow?
a. 240 J
b. 216 J
c. 144 J
d. 96 J
e. 75 J

____ 2. A horizontal force of 200 N is applied to a 55-kg cart across a 10-m level surface. If the cart accelerates at 2.0 m/s^2, then what is the work done by the force of friction as it acts to retard the motion of the cart?
a. -1 100 J
b. -900 J
c. -800 J
d. -700 J
e. -600 J

____ 3. If both mass and velocity of a ball are tripled, the kinetic energy is increased by a factor of:
a. 3.
b. 6.
c. 9.
d. 27.
e. 81.

____ 4. A professional skier reaches a speed of 56 m/s on a 30° ski slope. Ignoring friction, what was the minimum distance along the slope the skier would have had to travel, starting from rest?
a. 110 m
b. 160 m
c. 320 m
d. 640 m
e. 720 m

____ 5. When an object is dropped from a tower, what is the effect of the air resistance as it falls?
a. does positive work
b. increases the object's kinetic energy
c. increases the object's potential energy
d. increases the total energy of the object
e. None of the above choices are valid.

____ 6. Samantha pushes a 50-N crate up a ramp 25.0 m in length and inclined at 10° with the horizontal. What potential energy change does the crate experience?
a. 13 J
b. 55 J
c. 120 J
d. 220 J
e. 280 J

Appendix I. Sample questions from the chapter four pre-quiz.

Name: ____________________ **Class:** ______________ **Date:** ________ **ID: A**

AP physic C - Quiz chapter 4 Newton's Laws of Motion (Part I)

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. If we know that a nonzero net force is acting on an object, which of the following must we assume regarding the object's condition? The object is:
a. at rest.
b. moving with a constant velocity.
c. being accelerated.
d. losing mass.
e. both a and b are correct.

____ 2. A cart of weight 20 N is accelerated across a level surface at 0.15 m/s^2. What net force acts on the wagon? ($g = 9.8$ m/s^2)
a. 0.92 N
b. 0.31 N
c. 3.0 N
d. 4.5 N
e. 5.2 N

____ 3. A rock is rolled in the sand. It starts at 5.0 m/s, moves in a straight line for a distance of 3.0 m, and then stops. What is the magnitude of the average acceleration?
a. 1.8 m/s^2
b. 4.2 m/s^2
c. 5.4 m/s^2
d. 6.2 m/s^2
e. 7.1 m/s^2

____ 4. Rita accelerates a 0.40-kg ball from rest to 9.0 m/s during the 0.15 s in which her foot is in contact with the ball. What average force does she apply to the ball during the kick?
a. 48 N
b. 72 N
c. 24 N
d. 60 N
e. 76 N

____ 5. A 70.0-kg man jumps 1.00 m down onto a concrete walkway. His downward motion stops in 0.0200 seconds. If he forgets to bend his knees, what force is transmitted to his leg bones?
a. 15 500 N
b. 7 010 N
c. 4 900 N
d. 3 500 N
e. 2.600 N

____ 6. The accelerating force of the wind on a small 200-kg sailboat is 707 N northeast. If the drag of the keel is 500 N acting west, what is the acceleration of the boat?
a. 1.5 m/s^2 due east
b. 2.5 m/s^2 due north
c. 3.0 m/s^2 northeast
d. 2.0 m/s^2 north by northwest
e. 1.5 m/s^2 due west

Appendix J. Sample questions from the chapter four post-quiz.

Name: ____________________ **Class:** ________________ **Date:** _________ **ID: A**

AP physics C - Quiz chapter 4 Newton's Laws of Motion (PartII)

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. An automobile of mass 2 000 kg moving at 30 m/s is braked suddenly with a constant braking force of 10 000 N. How far does the car travel before stopping?
a. 45 m
b. 90 m
c. 135 m
d. 180 m
e. 210 m

____ 2. A shot-putter moves his arm and the 7.0-kg shot through a distance of 1.0 m, giving the shot a velocity of 10 m/s from rest. Find the average force exerted on the shot during this time.
a. 175 N
b. 350 N
c. 525 N
d. 700 N
e. 855 N

____ 3. A baseball batter hits an incoming 40-m/s fastball. The ball leaves the bat at 50 m/s after a ball-on-bat contact time of 0.030 s. What is the force exerted on the 0.15-kg baseball?
a. 450 N
b. 250 N
c. 140 N
d. 90 N
e. 50 N

____ 4. In the terminology *a 500-N block*, the *500-N* refers to the block's:
a. mass.
b. force.
c. weight.
d. None of the above.
e. Both a and c are correct.

____ 5. The statement by Newton that "for every action there is an opposite but equal reaction" is regarded as which of his laws of motion?
a. first
b. second
c. third
d. fourth
e. None of the above.

____ 6. Two blocks, joined by a string, have masses of 6.0 and 9.0 kg. They rest on a frictionless horizontal surface. A 2nd string, attached only to the 9-kg block, has horizontal force = 30 N applied to it. Both blocks accelerate. Find the tension in the string between the blocks.
a. 18 N
b. 28 N
c. 12 N
d. 15 N
e. 16 N