EFFECTS OF COMPETITION IN THE CONCEPTUAL PHYSICS CLASSROOM

by

Bruce Clark

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2018

©COPYRIGHT

by

Bruce Clark

2018

All Rights Reserved

ACKNOWLEDGEMENT

I would like to thank Lewiston-Altura High School for making my graduate experience possible. The district has always believed in me as a science teacher and have given me freedom to do and teach what I think benefits the students most. They have allowed me to first off, create the conceptual physics course and second teach it how I saw fit. Both of which allowed me to pursue my passions in teaching.

Thank you to the entire MSSE staff at Montana State University: Diana Paterson, Walter Woolbaugh, and Marcie Reuer for directly working with me through the capstone process, answering numerous questions, providing support and putting my needs first throughout the entire process. Also, I'd like to thank all of my other coursework teachers, in particular, my field course professors for reigniting my curiosity and my love of education. What a truly wonderful and complete program that Montana State offers. I do not know of any other programs that compare.

I would like to thank my family for supporting my goals and passions throughout my life. As teachers they have always understood the value of education and have instilled those values in me. I'd also like to thank all of the teachers and coaches I have had along the way for each providing their own piece of the puzzle in my education.

And lastly I would like to thank Emily Zinck. This project would not have been possible without her. Not only has she been a fantastic mentor and inspiration but a wonderful friend and human being. She has supported me for years; getting my physics license, developing new classes, and most importantly helping to keep me on my feet and functioning during the capstone process. She was my original source for the *Junk Box*

Wars and has continued to be a mentor and inspiration to this day. This capstone would not have been possible without her.

TABLE OF CONTENT

1. INTRODUCTION AND BACKGROUND 1

2. CONCEPTUAL FRAMEWORK 4

3. METHODOLOGY 9

4. DATA AND ANALYSIS 13

5. INTERPRETATION AND CONCLUSION 18

6. VALUE 21

REFERENCES CITED 25

APPENDICES 28

APPENDIX A: IRB Exemption Letter 29
APPENDIX B: Unit 4 Conceptual Pre and Posttest 31
APPENDIX C: Unit 5 conceptual pre and posttest 35
APPENDIX D: Pre and Post Unit Likert Survey 39
APPENDIX E: Sample Junk Box War Rubric 44

LIST OF TABLES

1. Gamification Outline 4

2. Data Triangulation Matrix 9

LIST OF FIGURES

1. Unit 4 Pretreatment and Post Treatment Assessment Scores 14

2. Unit 5 Pretreatment and Post Treatment Assessment Scores 15

3. Average Student Survey Responses.....16

4. Quantitative Pretreatment Survey Responses 17

5. Quantitative Post Treatment Survey Responses 18

ABSTRACT

Student engagement has been an issue plaguing modern classroom across the country. Students who struggle academically tend to lack motivation to be an active participant in the classroom causing them to fall further behind, thus creating a positive feedback loop in which students that struggle become less and less involved in the classroom. Competition, despite its occasional negative press, can be a positive motivator for people and in particular students. This study investigated whether competition in various labs throughout a conceptual physics course positively impacted student engagement in the classroom. This study also investigated the effects of competition on student comprehension as well as its effects on the student's general attitude towards education. The results indicated that controlled, or adaptive competition increased student's engagement in the conceptual physics classroom and also positively impacted their attitudes towards school and their understanding of physical science on the conceptual level.

INTRODUCTION AND BACKGROUND

I teach at Lewiston-Altura High School, a public high school in southeastern Minnesota. It is a small, rural school district with a 9-12 enrollment of 235 students. The high school is located in the town of Lewiston, which has a population of 1,620 people. The majority of the economy of the district comes from agriculture. The district is 90% white with the rest being predominantly Hispanic. In 2016, 48% of the students in the district scored proficient on their science standardized test. I have been the biology teacher for the high school for the last six years and have also taught physics classes for the last three school years.

The competitions-based techniques employed in this study were tested on a section of Conceptual Physics students. The class consisted of 20 juniors and seniors. Of the class, 60% of the students are on free and reduced lunch, compared to the school rate of 35% (Vickie Speltz, personal communication, October 9th, 2017), indicating that 60% of the students are near or below the poverty line. Five students are on either an IEP, and individual education plan, or a 504 plan, a tool used to help students with mild learning disabilities, both of these are indicative of students needing special education services. The average GPA for the class is 2.28 out of a four-point scale. In the conceptual physics class, 18 of the students are Caucasian, one is Hispanic, and one is African American.

Conceptual physics is a class that I have created in order to accommodate to our students who need to fulfill the state requirements for science, yet do not have much desire to go into a science related field or a traditional four-year college. In 2015, the state of Minnesota began requiring students to take either physics or chemistry in order to

graduate. The first year of this mandate my school offered chemistry in the community as a way to fulfil this requirement. That particular class, taught by my colleague Emily Zinck was not conducive to our students and their learning styles. There was little appeal to our more kinesthetic learners. As a result, I created conceptual physics as an alternative option to better serve our student population. Many students in the class have struggled in their freshman and sophomore science classes. The students in general tend to be more mechanically inclined as several come from agricultural families or work jobs that are centered around manual labor. In the class we tend to focus on the general concepts of Newtonian physics and apply some algebra-based math to physics problems.

While looking for ways to engage more students in class and teach physics through model making, I was given a series of labs from my colleague Emily Zinck who teaches traditional the physics class at Lewiston-Altura. The labs, called Junk Box Wars, involved using an assigned variety of everyday objects, in order to build a machine capable of the given challenge. Examples include, building rubber band and moue-trap powered cars, catapults and parachutes. This is the kind of project that resonates with the population of students that typically take conceptual physics.

In addition to model making in labs, I was looking for more ways to engage students in science education. Science offers all students, regardless of their ability level, valuable tools to use in life. The students in my conceptual physics class may not necessarily benefit from the content of physics, but may benefit from learning of the scientific process, team work skills and setting goals to work towards that are tangible. I found the answer engaging students in my track and field program. I am currently the

head track and field coach for the boys and girls at my high school. I have coached the boys for the past five seasons. In track, I keep records of and post several statistics of our team. Over the years I have noticed that athletes gravitate towards the record boards and like to compare themselves to other athletes on the team or to the top ten performers that I have coached. This is a constant source of motivation for my athletes, the feeling of adaptive competition in practice and meets. During my six years of teaching I have also seen many similar outcomes in student engagement when games or competition are involved. For the last few years I have handed out small awards for winning review games, doing well on tests, and having all missing work turned in. This, in turn, creates much more enthusiasm and engagement in the classroom.

On top of my experience coaching track and field, I also gained some motivation from reading and listening to Po Bronson's work, *Top Dog*. In the book, Bronson investigates the effects of competition in a variety of settings. Bronson argues that we, as a society have attached a negative connotation to the idea of competition and that we have ignored the positive effects of *adaptive competition*. Adaptive competition, as it is defined by Bronson, is fair competition, or competition where both parties have a chance to succeed. Similarly, students that are equally matched tend to do quite well when placed in a competitive group of their peers (Carrell, 2009). However, it is important to point out that large gaps in ability can create maladaptive competition or competition that actually lowers performance (Brown, 2011). Adaptive competition is what I directly encourage on my track and field team. I felt the need to apply this approach to my conceptual physics class, as a way to motivate students.

Using this experience, I saw a way I could incorporate this into my classroom. This lead to the formation of my focus statement of, “how can competitive labs influence student engagement in the classroom?” In addition, the following follow-up question was also addressed, “how do competitive labs affect formative assessment scores?” To research these questions, I have developed a mixed methods action research plan.

CONCEPTUAL FRAMEWORK

Apathy and student engagement have been struggles for a multitude of modern classrooms. There are several ways that researchers and teachers are trying to combat this. From gamification to project- based learning, professionals are looking at more ways for the students to take ownership over their own education. Yildirim Ibrahim recently looked at the effects of gamifying lessons with university students in his Elementary Mathematics Education classes. His goal was to study “student achievement and attitude towards the lessons” This is essentially turning the classroom into a game board, having students compete against each other and the system. Ibrahim used the follow principles of gamification to design his lessons. Table 1.

1. Knows that the lesson is actually a game and succeeds in finishing the game by completing the tasks. 2. Is aware of the advancement structure and fulfills the requirements. 3. Cooperates with friends inside and outside of the class. 4. Is more successful in a favorable competitive environment. 5. Knows what is required to earn points and earns points by putting his/her knowledge into practice. 6. Knows what is required to earn experience points (xp) and earns experience points by putting his/her knowledge into practice. 7. Knows what is required to level up and levels up by putting his/her knowledge into practice. 8. Knows what is required to earn badges and earns badges by putting his/her knowledge into practice. 9. Knows what is a leaderboard and makes efforts to advance in the league.

This kind of gamification of the classroom has become a popular trend in education. The lessons consisted of achievements, badges, leaderboards and voluntary work outside of class. The top five principles were principles that could be applied towards making competitive labs in the conceptual physics class. What Ibrahim found was that student achievement rose slightly, 5-6%, as did the attitudes towards his class. While gamification has been proven as a positive motivator in education it is often a big undertaking, requiring educators to change large portions of their curriculum in order to structure a gamified classroom. The driving factor of gamification competition. Competition can easily be incorporated into the classroom without the need to build an entire curriculum around it.

There were several studies showing the effects of competition on achievement. One of the key things to consider in the studies was not only the effects but what kinds of competition lead to success and what kinds were more harmful than no competition at all. Corbett (2012) examined how various forms of competition led to varying results in cycling. During the study participants completed a 2,000m time trial. From there the participants completed a second time trial with a computer-generated biker on the screen to "race against" in reality the other biker was a computer-generated version of their previous time trial, but contestants who believed that in fact it was a head to head competition. The study concluded that head-to-head competition improved the participants' performance.

However, there is a common theme when researching competition and that is adaptive competition versus maladaptive competition. Adaptive competition has been

found to increase performance as a whole whereas maladaptive competition can drastically reduce performance. There are several conditions where adaptive competition can turn into competition, Po Bronson points this out in his book, *Top Dog: The Science of Competition. Maladaptive competition* can happen when the competitors are not evenly matched. Humans have an innate sense of fairness and once an unfair situation in detected most people shut down and no longer strive to compete. Another factor that can lead to maladaptive competition is when there are too many competitors. Corbett saw the best results when they practiced head to head competition, Garcia and Tor (2009) studied the opposite of this effect in "The N-factor: More competitors, less competition". This article looked at a variety of samples including social comparisons and SAT test scores. They found that increasing the number of students taking the SAT at a testing site decreased the group's average. In general, they discussed how standardized tests such as the ACT and SAT are poor competitive tests because of many factors, one being numbers of competitors, two being the timeliness of the feedback and three being not being able to see or know who the competition is against. The study also looked at testing speed in a controlled setting and found that students given the goal of trying to finish in the top 20% of their class completed the quizzes much faster if told that their class size was 10 students versus 100 students (Garcia, 2009). Ultimately this shows competition not only has to be fair, but it also has to be localized. People are more likely to benefit from competition when that competition occurs in a comprehendible group size.

Looking at student engagement can be a tricky process. Every teacher can tell when students are engaged or not in their classroom, but it is tricky to measure this on a

long term scale. Sinatra, et. al. looked at this dilemma in their paper, “The Challenges of Defining and Measuring Student Engagement in Science” (2015). The group breaks engagement down into four different types of engagement; behavioral engagement, emotional engagement, cognitive engagement, agentic engagement. The first three types all describe a scenario in which students are reactive to their environments. The authors discuss *agentic engagement* as students taking the initiative or lighting their own fire so to speak. The group also suggested a blend of two measures for engagement. Firstly, it has to be determined what engagement looks like and which of the four realms of engagement is being observed. Secondly, a researcher must use both the power of observation as well as use student surveys in retrospect. From there they suggest a continuum of observation, so it is not merely if a student is engaged or not but ranking that student on a scale.

It is clear to see that there is a correlation between adding some level of competition and increased individual and group performances. Many institutions have started to incorporate some of these themes into campus life. Ivy league schools and military academies alike have begun to pay attention to how they group their incoming students. What they have found is that groups that are grouped together of similar ability levels tend to push each other and compete for success, ultimately enhancing not only their own performance, but also the group’s achievement level (Carrel, 2009). Conversely, groups that contained a large achievement gap tended to struggle (Brown, 2011). The students in the lower half of the class were discouraged by their superior classmates and the students in the top half of the class became lazy and were not

challenged by their discouraged peers (Angrist, 2009). This is a parallel set up to the conceptual physics classroom. At Lewiston-Altura High School these students would have been assigned courses and classmates at random for science class beginning as elementary school students all the way until their 10th grade year. Conceptual physics for many is the first time they have been grouped with very comparable classmates at both an achievement and motivational level. This sets a level playing field for adaptive competition for labs and assignments in the classroom.

Competition alone can be a risky motivator for students and people alike. A class of 20 individuals competing against one another would produce 1 winner and 19 losers. This can lead to feelings of helplessness and isolation, both of which can lead to a total loss of engagement or motivation. While a handful of individuals would continue to thrive a large portion of the class would become frustrated and elect to put even less effort in (Medvec, 1995). This is why it is crucial to create teams for competitions. We see this in sports numerous times. The top third of motivated individuals on the team would compete and be successful regardless of the team aspect. It is the bottom two-thirds of the motivated individuals that only really invest time and effort when they feel a part of a team (Erev, 1993). The same can be applied to the conceptual physics classroom. Many would excel on an individual level but to engage the largest number of individuals it is crucial to include the team aspect. Not only does it promote competition and engagement it also helps develop crucial interpersonal skills and can give students a sense of belonging (Walton, 2012).

Adaptive competition can have positive impacts and enhance participation and achievement in a variety of activities. In order to tap into those benefits in education certain guidelines must be met. The students competing with one another must be similarly skilled. A minimal achievement gap keeps students from being discouraged by far more successful peers. Competition sizes should be small. The human brain responds better to smaller fields of competitors versus hundreds of competitors. Also perceived fairness is important to establish a healthy competitive atmosphere. Students have to believe that the playing field is at least close to level. It is also critical that the students are not solely evaluated on where they rank in the class. It is important to keep their rank among their peers as a small portion of their score leaving the bulk of the points in other categories evaluating their proficiency and effort. For example, points for completing the project requirements and working together as team should outweigh their rank in the class. These things together are essential for successful competition.

METHODOLOGY

The purpose of this study was to determine the effect of competition-based labs on student engagement in the conceptual physics classroom and secondarily the effects of those labs on science comprehension. Students competed against each other periodically throughout the class and given assessments as well as surveys to determine the effectiveness of that competition. The data triangulation matrix is shown below (Table 2).

Table 2
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Primary Question:	Likert Survey responses	Post treatment student interviews	Anecdotal Observations and

Will student engagement be directly impacted by use of competitive labs in the classroom?			Student Interviews
Secondary Question: *Will student achievement be directly impacted by use of competitive labs in the classroom?*	Pre and post treatment assessments	Likert Survey Responses	Post treatment student interviews

Study Demographics

In the study, 20 Lewiston-Altura high school conceptual physics students participated in this study. Of the 20 students 12 or 60% are on free and reduced lunch, indicating that 60 % are near or below the poverty line. Five students are on either an IEP, Individualized education plan, or a 504 plan, a plan used to help students with a learning disability. The average GPA for the class is 2.28 out of a four-point scale. 18 of the students are Caucasian, one is Hispanic and one is African American.

Students living in the Lewiston – Altura School District are generally exposed to a blue-collar lifestyle. It is an old town, established in the late 1800's and currently has a population of 1,620 people. The town relies primarily on agriculture for its economy. Dairy, Corn, Soy Beans and beef are primarily grown and harvested. Many students in my classroom have connections to the agricultural community, either working on a farm or living in a family that owns some farm land.

Treatment Description

The treatment period began in mid-fall with our Newtonian motion unit. The study ran through the end of the quarter, covering a total of two units. Students were given a pretest and a prelab survey (Appendices B and C) before starting the competitive lab. Students were then given the parameters of the lab, their rubric and their tray of supplies. The different labs varied in length of time, supplies used, task to be completed, and group size. After the competition of the lab, students were then asked to take a posttest as well as another survey.

The competition would start by giving students the parameters of the lab. Student would be told, (1) what the goal or objective of the lab would be (2) what and how many supplies they would be given to use (3) how the competition would be structured and finally (4) a rubric describing the grading process and how they would earn points on the projects. Students were then allowed to divide themselves as they wished into groups of no less than two and no more than five. Each group was given a tray of materials to use for their model or project and groups were shown the competition area or requirements, sometimes this was a ramp their car had to drive up, or the target for an egg drop parachute, etc. The groups were then given varying amounts of time to work on their projects. Some projects, such as the mouse trap cars, were given multiple periods for students to build and test before having the competition. Other competitions might exist entirely in a single 80 – minute class period.

As the students brainstormed, built and tested their projects, I would be available in the lab to answer questions or to clarify rules of the competition. I purposely never

offered much help to groups. Occasionally, if I felt a group was very far behind or becoming frustrated in the process I would give them a few small pointers to help them get moving in the right direction. Students were also encouraged to do whatever research they wanted to for their projects. During the building process students put their projects through several tests resulting in the students making dozens of small alterations and fixes in order to try to build the best model that they could. At the end of each work day I collected each groups model to ensure that no additional parts were added.

For competitions, students were given a certain amount of time and a certain number of trials that they could compete in. I would give the students a deadline as to when they needed to be ready to compete. At that point all supplies were put away and everyone in the class would move to the area of competition. Oftentimes, this would be the hallway or the front of my room, but it could also include the gym or an area outside. During competition one group would go at a time while the other groups watched. I would announce the time, distance or score that each project achieved to the whole class. After their initial trial students were given a short amount of time to fix or make small modifications to their project, maybe a piece of tape here and there and fixing the angle of the wheels etc. After their final test I would give the students a score based on what was laid out in their rubric. At this point in time students would complete some follow up questions and deconstruct their projects.

Data Collection and Analysis Techniques

To collect data on student engagement students were asked to complete the same survey throughout the study (Appendix D) The survey was distributed before

participating in the competitive lab and once the competition was completed. The survey consists of a variety of statements on which students scored themselves on a Likert scale, *1 Strongly Disagree, 2 Disagree, 3 Neutral, 4 Agree, and 5 Strongly Agree*. The statements were chosen to reflect a variety of factors to show how engaged students are in the science classroom and the effectiveness of the labs. The results from all of the surveys were then compiled to reflect a class average of scores as well as the standard deviation. The data collection instruments are illustrated in the table below.

Prior to completing the survey, students were given a pretest of the concepts being tested (Appendix 2). These pretests did not count towards students grades and were often designed to be conceptual. The tests consisted of mainly multiple choice or true-false questions and very little math. The test were taken prior to the Junk Box War labs. The same test was taken the day after the *Junk Box War* lab and evaluated as a posttest.

For the study I used our *Junk Box War* labs and added a competitive component to the grading rubric. Students were given rubrics for each project which included several categories including; teamwork, being on task, design, uniqueness and the final category was related to how well their model compared to the rest of the class's (Appendix E). A portion of the student's grade was determined based up their rank among their classmates. Other parts of their grade promote skills that should lead them to a successful test.

DATA AND ANALYSIS

Students were evaluated for two different parameters, One, does competition affect student engagement in the science classroom and, two, does competition affect

student achievement in the classroom. The results from the assessments and surveys are shown below.

The conceptual assessments tested the students on a variety of skills. Mainly, (1) how objects interact related to each other, (2) how altering the inputs of a given scenario can affect other variables, and (3) general knowledge of the physical science concepts at

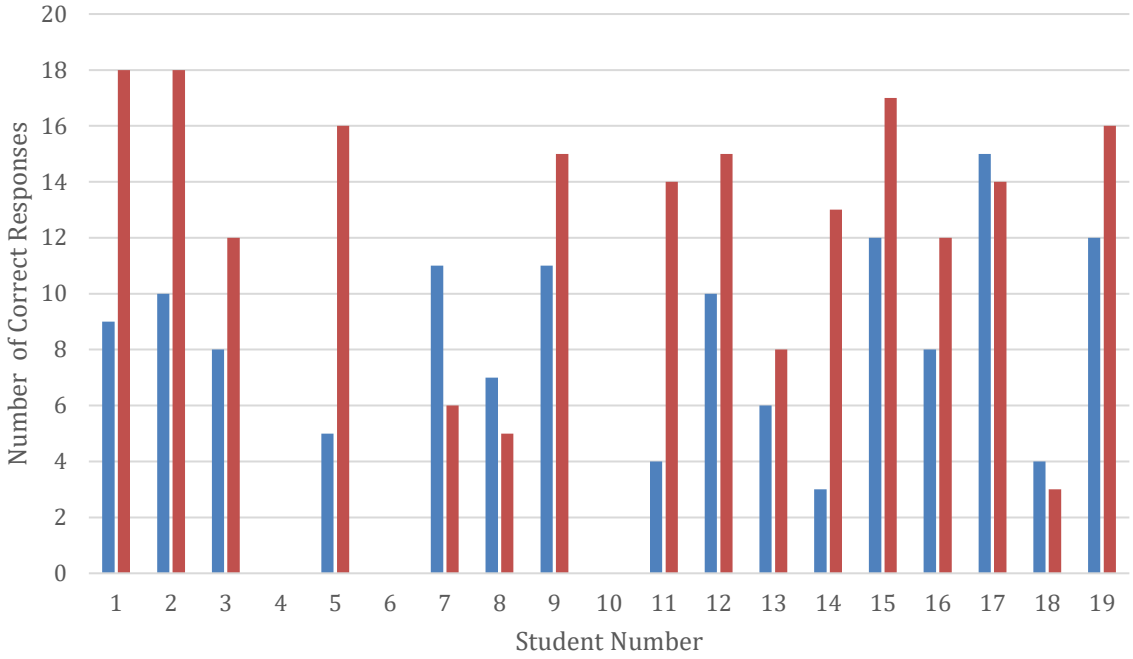


Figure 1. Pre (blue bars) and post (red bars) test assessment scores Unit 4 assessment scores. Students 4,6, and 10 were absent for testing. Scores were out of 20 possible points.

hand. The results indicate an increase of students' conceptual understanding of the interaction of physical objects by an average of 49.6% and 23.8% for the two units covered. While the median increase from 42% to 70 % in Unit 1 and from 44% to 56% in Unit 2. Both gains were determined to be significant when running a paired t-test. Unit 4 with a p-value of .0015 and Unit 5 with a p-value of .0037 are both considered to be significant growth. Now, while these appear like large increases, it should also be noted that some of the material was covered during the course of the labs as student questions

came up on various topics. Figure 1 and 2 show the results of the pretest and posttest for the students who participated in both.

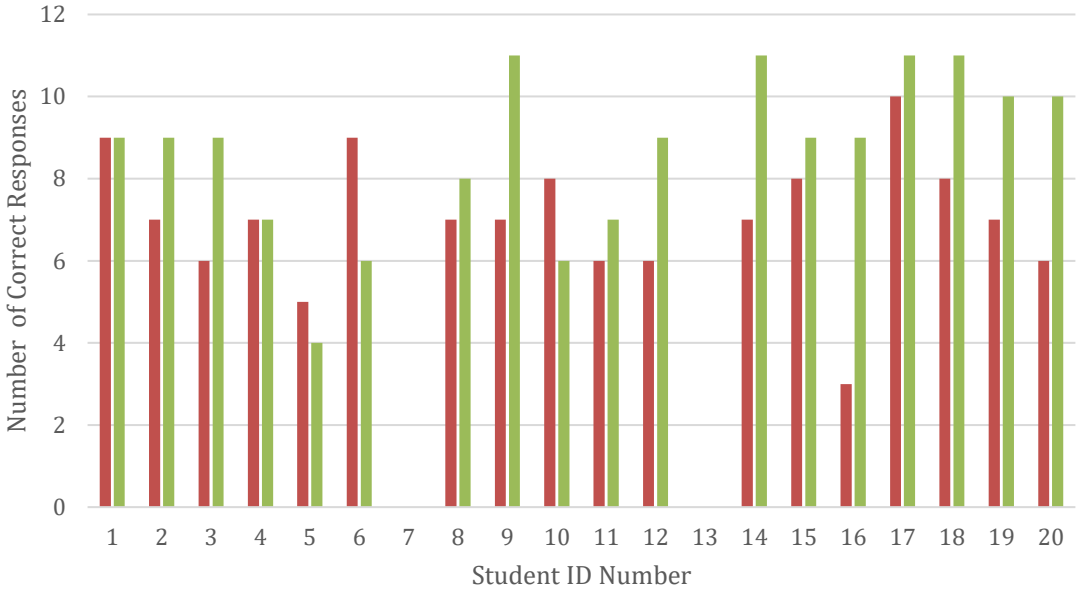


Figure 2. Pre (red bars) and post (green bars) treatment assessment scores. Students 7 and 13 were absent and their scores have been excluded. Assessments were out of 16 possible points.

Survey Responses

Much can be gleaned from the survey responses given throughout the unit. While the students showed a very slight increase from their original attitude of "I feel engaged in science class" normalized gain of 5.5%. Using a paired t-test we see get a p value of .19, indicating that it is insignificant growth. The largest gains made were in the reflective questions of, "I like school." "I do well in science class" and "Labs help me understand the content." with normalized gains of 18.8%, 22.3% and 15.1% respectively. Survey responses to the question, "I do well in science class" show significant gain.

When using a paired t-test a p-value of .006 was achieved, indicating that in fact the growth was significant. Answers to the question, “I feel like the labs we do in science class help me understand the content” Also showed significant gains. When using a paired t-test the results indicate a p-value of .019, indicating significant gain. The rest of the results do not have significant growth. Two categories showed regression throughout the course of the treatment. “I like working in groups.” regressed 2.4% and “I am bored a lot in school.” increased 5.6%. figure 3 below shows the mean of the class responses to each questions, neither were determined to be significant.

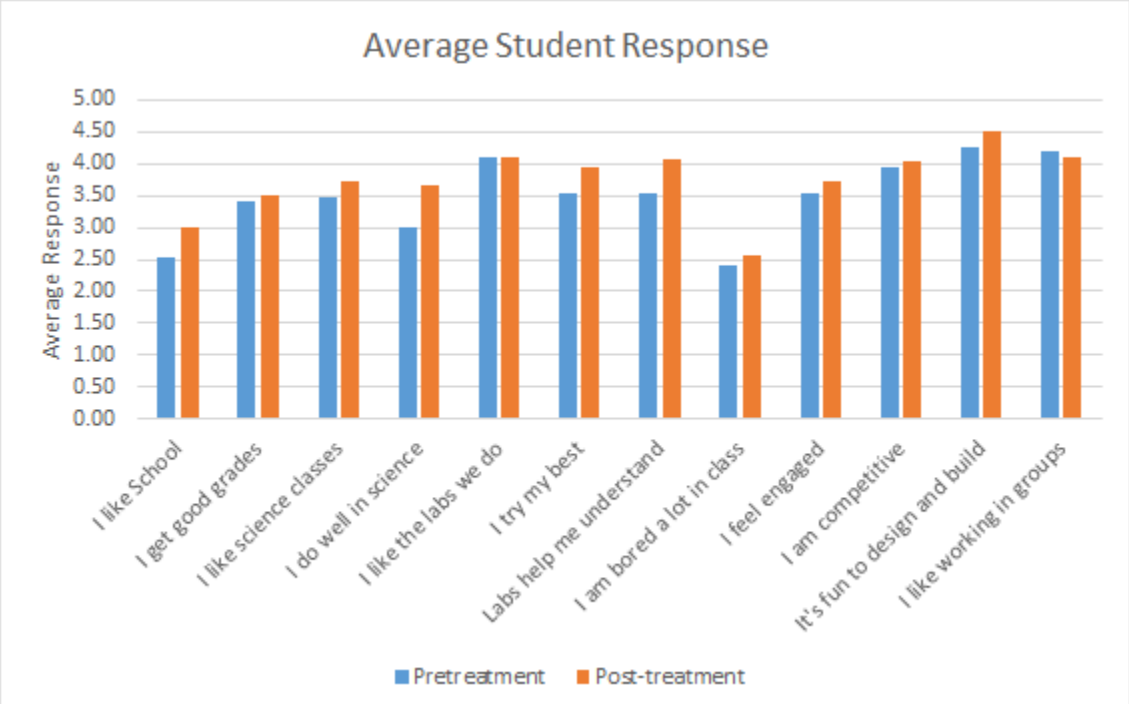


Figure 3. Average of student survey responses gathered before the treatments and after the treatments. A 5 represents Strongly Agree. A 1 represents Strongly Disagree.

More telling than the average gains found in student responses is the increase in the number of students that either agreed or strongly agreed about topics related to involvement and success in school. The question, “I feel like I try my best in science class” went from nine responses of neutral or below down to six. “I like school” went from 16 responses of neutral or below down to 11. “I feel engaged in science class” went from 11 neutrals or below down to seven. “I do well in science class” had six “Disagree” responses pretreatment and zero responses for either ‘disagree’ or ‘strongly disagree’. Figures 4 and 5 illustrate the quantity of response in the pre and post treatment surveys.

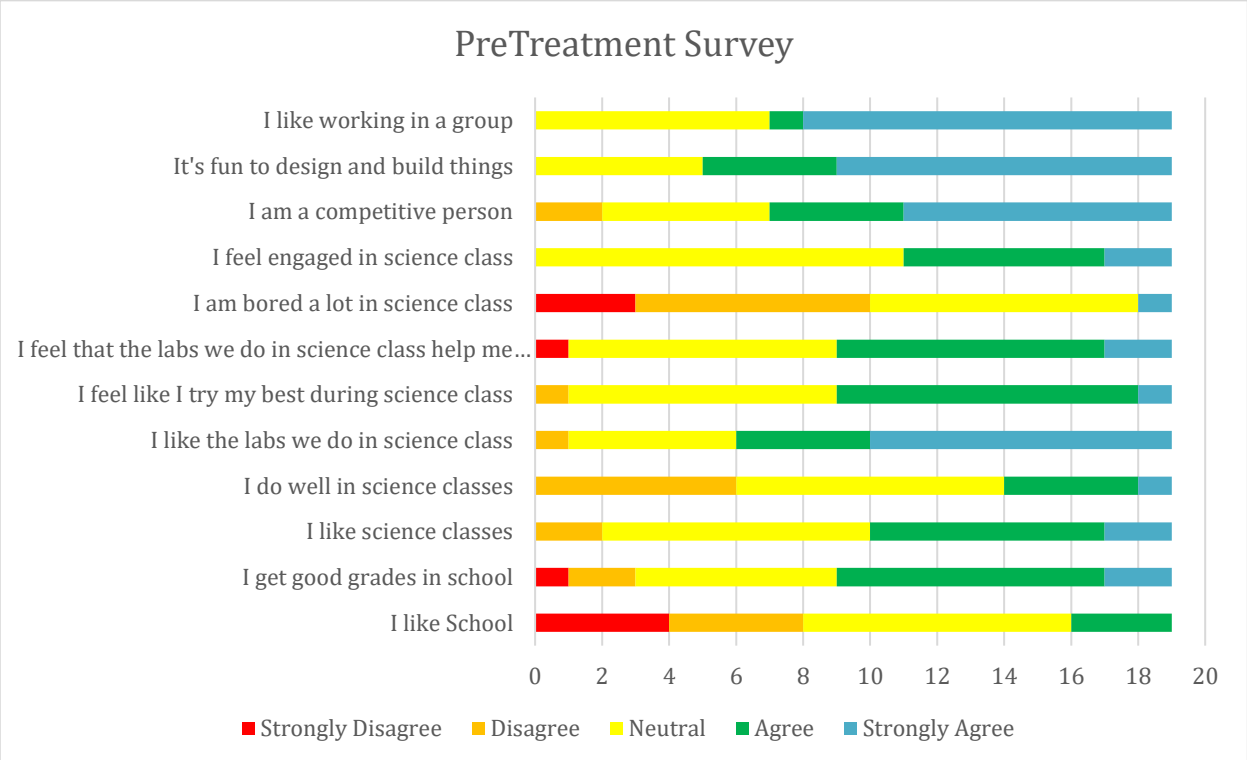


Figure 4. Quantitative list of student survey responses taken pretreatment. Strongly Disagree, indicated by a red bar and furthest to the left on the graph. Strongly Agree, indicated by a blue bar furthest to the right on the graph.

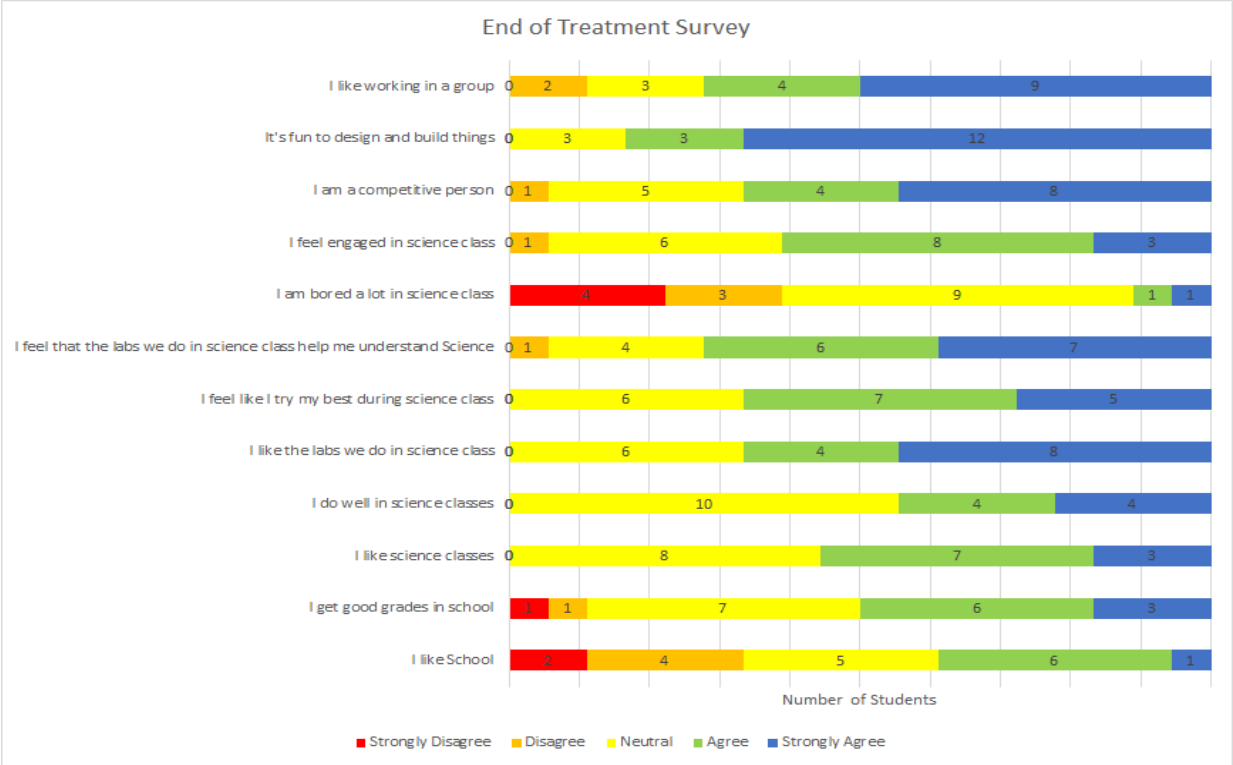


Figure 5. Quantitative list of student survey responses taken post-treatment. Strongly Disagree, indicated by a red bar and furthest to the left on the graph. Strongly Agree, indicated by a blue bar furthest to the right on the graph.

INTERPRETATION AND CONCLUSION

The goal of the research project was to determine the effect of competitive labs on student engagement and comprehension in the conceptual physics classroom. From the interviews, pre and post treatment Likert data and conceptual assessments it is clear that students enjoyed school and science class more so when competitive labs were used. Surveys and interviews showed that students enjoyed coming to school, specifically science class more once the competitive lab portion of the class began. Students also felt more confident in their physics skills illustrated by the 22.3% gain in responses from the question, “I do well in science class.”

From the pre and post treatment Likert data it is clear that the students did not become more competitive or in the least did not feel that they identified as a competitive person any more so than they did before the treatment started, with only a 2.6 % increase. This disconnect illustrates the effect of competition itself. The competitive labs made students more excited to come to class however they themselves did not feel that it turned them into a competitive person, rather just help them enjoy science class and school.

Beyond the quantitative data there were other noticeable improvements in the classroom dynamics of the group. As the treatment progressed there were large gains in comradery with the groups. Not only were students more comfortable with the groups that they were working in, but they also felt a connection with the groups they were competing against. Certain groups would gain reputations for being the first group done, or being the most creative group, or being a group that came up with successful models. Students enjoyed this sense of identity and began to take pride in their work as a result. This is a benefit that would typically be missing, or much less obvious, with traditional labs in the science classroom.

In addition to taking pride in their work students also achieved a greater understanding of the content. Substantial gains from pretest to posttest indicate that students comprehended lessons they learned while building their models and participating in class. Many students also wrote in their surveys, “The hands-on nature of the labs helped me understand the material better.” As a result of spending so much time building working models and competing with classmates, there was better student comprehension of mechanics.

The boys in the class seemed to respond tremendously to the treatment. Throughout the country, boys tend to struggle more with the current form of education. The study group exemplified this. Many of the boys sampled have struggled historically in science class and other classes throughout the day. During the course of the treatment, it became more and more apparent that the boys were becoming more interested in science class. For instance, the class had a day at the end of the year in which we had some extra time. I gave the students the option to watch a movie or participate in another Junk Box War, the class overwhelming chose the Junk Box War. Many students on that particular project spent time outside of the school day to come into the classroom to work on this project that was optional. I highly doubt this would have been the case had this been a traditional lab.

Adding competition to class rooms labs is a noisy process, both literally and figuratively. On the positive side students bring a lot of energy to class creating exciting competition days and events that students are passionate about in the physics classroom. The negative is also true. Group dynamics in the high school setting can change week to week even day to day. Throughout the project, students had some authentic conversations within their groups, not only about specific physics concepts but also about effort and ability. A project that does not function that way it is supposed to is a major source of frustration. High school students do not always know how to handle that frustration. This simulates real life situations for the students and forces them to learn how to cope and communicate with their peers while working towards a common goal.

Ultimately, through these competitions students became more confident in their own abilities and were more engaged in the school year. Conceptual physics took place from April to January. Typically, students are less excited about education as that first semester carries on, in this study I saw the opposite. Frequently, in response to survey questions students would write in, “The labs are a lot of fun”. Or students would respond, “The labs are awesome and I like competing in class.” This shows that some of those same students that have historically not enjoyed or experienced success in school were enjoyed some aspect of education. Some students even took and optional competition lab home over winter break so they could work on it. These are students that typically hate school taking extra work home because they enjoy it. This is the most important part of this study, the ability to motivate hard to reach students and give them the opportunity to experience success in the science classroom. For many, this was the first time that they enjoyed the educational process.

VALUE

Conceptual physics classes tend to be students who are not strong in science or students that struggle in general academically. Many students in conceptual physics are often bored in science classes and in their other core classes. Competitive labs are a way to open up the science classroom to a broader range of students. Students are learning principles of physics, clearly from their increase in exam scores, without directly focusing on those points. Students are able to engage other parts of the brains while working together as a group to solve a common problem, doing so against other classmates gives the extra incentive they need to generate excitement over the project.

This is evident in the last day before the end of winter break. Students were told there would be a video for the day and the students instead begged to have another *Junk Box War* instead. Beyond the improvement in test scores this is the kind of activity that gets the students that struggle to come to school every day interested in a class.

In addition to attitudes about class in general students were more excited to come to school. Several students scheduled appointments and absences around conceptual physics class. From the survey results it was clear that the students had a more positive view and outlook in regards to their education. Competitive labs gave students who were traditionally poor science students and gave them a reason to look forward to science class. In general, students who struggle in the traditional school setting benefit from including adaptive competition in the classroom. Students become more interested and more motivated when presented with a challenge or a chance to compete rather than simple completing a task.

After this study there will be definitely be a place for competition in all of my classes in the future. Doing this, I have seen the effects of competition on student engagement. For many students this gives incentive to participate in class, develop an understanding of the topics and be able to apply those principles. Beyond the impacts at an academic level I have seen great value in group competitions on a personal level for students. Many students seemed to come to class with a purpose on days they knew they were competing. On more than one occasion students would be knocking on my door during lunch to start working on their science projects. These are students that are in the class because they have historically struggled in science and yet they are searching out

extra time to commit to the class. Some themes of this motivation can be used in a variety of courses and aspects in life.

In addition to the growth that can be seen in individual skills a great benefit to group work, specifically group competitions are developing teamwork skills. As a coach I have always believed that sports have a much deeper benefit and purpose than just wins and losses. Team sports can develop a multitude of skills that can benefit a person throughout life. Developed this sense of teams or groups in the classroom has shown similar benefits. Students that would never participate in a group event now have a chance to develop inter personal skills that will only benefit them as they continue to go through life. To me, that is the biggest benefit of competing as teams in class. Students develop skills that are vital to working together, not only in the classroom but in society and in life.

Investigating competition in the classroom has been an eye-opening experience. It was incredible to see the students' reactions to adding something as simple as a little bit of competition against their peers. Not only did it get some students a little bit out of their comfort zones, but it also gave students an avenue to open up in front of the class and gave them some success in a subject they had never experienced success in before. As a teacher I will continue to look for more ways to incorporate elements of adaptive competition into my curriculum in a variety of classes and will continue to promote it to other areas of education. Adaptive competition appears to be an effective tool to make science class and education relevant to some students that are typically hard to reach.

As new educator I always saw myself teaching advanced classes. Out of college, I had thought I would be teaching those upper level classes to those honors-type students. To be honest, I had always thought teaching a conceptual level class was beneath me. After, completing this study and having a couple of years under my belt as an educator I find the opposite being true. I thoroughly enjoy working with conceptual physics type students every day. This study truly opened my mind and showed me that these students are not necessarily dumb and lazy but that the education system has left them behind and or the students are more focused on something else in their lives. Adding competition to the classroom showcased the best features of these students and gave them a way to be successful and take pride in their education.

REFERENCES CITED

Angrist, Joshua & Victor Lavy, (2009) "The Effects of High Stakes High School Achievement Awards: Evidence from a randomized Trial," *American Economic Review,* vol. 99 (4), pp. 1384-1414.

Bjornebekk, Gunnar, Torgrim Gjesme, & Robin Ulriksen, (2011) "Achievement Motives and Emotional Processes in Children During Problem-Solving: Two Experimental Studies of Their Relation to performance in Different Achievement Goal Conditions," *Motivation and Emotion,* vol. 35(4), pp. 351-367.

Bronson, Po, & Ashley Merryman (2013) "Top Dog. The Science of Winning and Losing." New York, NY Twelve

Brown, Jennifer, (2011) "Quitters never win: The (Adverse) Incentive Effects of Competing with Super Stars," *Journal of Politcal Economy,* vol. 119 (5), pp. 982-1013

Carrell, Scott E., (2009) "Does Your Cohort Matter? Measuring Peer Effects in College Achievement," *Journal of Labor Economics*, vol. 27 (3) pp. 439-464

Corbett, Jo, Martin J. Barwood, Alex Ouzounoglou, Richard Thelwell, Matthew Dicks. (2012) "Influence of Competition on Performance and Pacing During Cycling Exercise" *Medicine and Science in Sports and Exercise,* Vol. 44(3) pp. 509-515

Dillon, Robin L., & Catherine H. Tinsley, (2008) "How Near-Misses Influence Decision Making under Risk: A Missed Opportunity for Learning," *Management Science,* vol. 54 (8), pp.. 1425-1440.

Erev, Ido. Gary Bornstein, & Rachely Galili, (1993) "Constructive Intergroup Competition as a Solution to the Rider Problem: A Field Experiment," *Journal of Experimental Social Psychology,* vol. 29, pp. 463-478

Garcia, Stephen M., & Tos Avishalom (2009) "The N-effect: more Competitors, less Competition." *Psychological Science,* vol. 20 (7) pp. 871-877

Harrison, Lesley K., Samantha Denning, Helen L. Easton, Jennifer C. Hall, Victpria E. Burns, Christopher Ring, & Douglas Carroll (2001) "The Effects of Competition and Competitiveness on Cardiovascular Activity," *Psychophysiology,* vol. 38 (4), pp. 601-606

Jones, Marc, Carla Mijen, Paul Joseph McCarthy, & David Sheffield (2009) " A Theory of Challenge and Threat States in Athletes," *International Review of Sport and Exercise Psychology,* vol. 2 (2), pp. 1611-80.

Medvec, Victoria Husted. Scott F. Madey, & Thomas Gilovich, (1995) "When Less is More: Counterfactual Thinking and Satisfaction among Olympic Medalists" *Journal of Personality and Social Psychology,* vol. 69 (4), pp. 603-610.

Sinatra, Gale M., Heddy, Benjamin C., Lombardi, Doug. (2015) "The Challenges of Defining and Measuring Student Engagement in Science" *Educational Psychologist,* vol. 50 (1), pp. 1-13

Speltz, Vicky. (October 9th, 2017). Personal correspondence

Tomm, Tracy. "Junk Box Wars" *The Science Spot,* *http://sciencespot.net/Pages/junkbox.html*

Walton, Gregory M. Geoffery L. Cohen, David Cwir, & Steven J. Spencer (2012), "Mere Belonging: The Power of Social Connections," *Journal of Personality & Social Psychology,* vol. 102 (3), pp. 513-522.

Yildirm, Ibrahim (2017) "The Effects of Gamification-based Teaching Practices on Student Achievement and Students' Attitudes Toward Lessons" *The Internet and Higher Education,* Vol. 33, pp. 86-92

Zinck, Emily. (August, 2017). Personal correspondence

APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-4707
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-4706
cherylj@montana.edu

MEMORANDUM

TO: Bruce Clark and Marcie Reuer

FROM: Mark Quinn Mark Quinn Chg
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 14, 2017

RE: *"The Effects of Competition Based Labs in the Conceptual Physics Classroom" [BC111417-EX]*

The above research, described in your submission of November 14, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

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

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

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

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

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

APPENDIX B

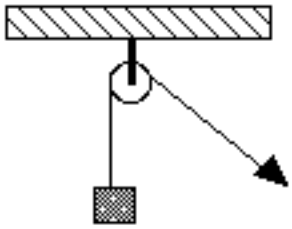
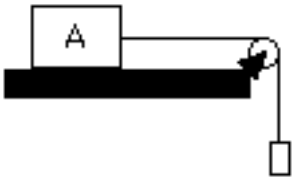
UNIT 4 – CONCEPTUAL PRE AND POST TEST

Student ID Number _____

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

UNIT IV: Assessment

For questions 1-4, draw the force diagram to represent the situation.

1. The box is raised at constant speed. 	
2. The box moves to the left at constant speed. 	
3. The weight pulls block A across a frictionless table. 	
4. The box is motionless. 	

For questions 5 -10, it is possible to have MORE THAN ONE correct answer.

5. A block of dry ice resting on a table is given a *brief push*. A moment later, which of the following forces act on the block?

a. the force of the push

b. a normal force

33

c. kinetic friction
d. the force of gravity

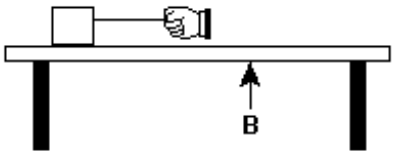
6. Which of the following describes the motion of the block? The block

a. moves at constant speed
b. slows down gradually to a stop.
c. continues at constant speed for a while, then slows down
d. accelerates constantly.

For questions 7 - 10 refer to the diagram below. A student attaches a string to the block of dry ice on the table, and *pulls steadily* on the block.

7. Which of the following forces act on the block?

a. the towing force
b. a normal force
c. kinetic friction
d. the force of gravity



8. Which of the following describes the motion of the block while it is on the table? The block

a. moves at constant speed.
b. slows down gradually to a stop.
c. speeds up for a bit, then moves at constant speed.
d. accelerates constantly.

9. When the block reaches point B, the string breaks. Which of the following describes the motion of the block? The block

a. moves at constant speed.
b. begins to slow immediately.
c. continues at constant speed for a while, then slows down.
d. continues to accelerate.

10. Eventually, the block reaches the edge of the table. After the block leaves the table, which of the following forces act on the block?

a. the force of motion
b. a normal force
c. kinetic friction
d. the force of gravity

11. As a ball falls, consider one force to be the pull of the earth on the ball. What is the pair to this force?

a. air resistance acting against the ball.
b. the pull of the ball on the earth.
c. non-existent in this case.
d. none of these.

12. A horse exerts a 500 N force on a heavy wagon, causing it to accelerate. What force does the wagon exert on the horse?

a. less than 500 N.
b. 500 N.
c. more than 500 N.
d. it's not possible to tell.

13. You're in the back of a friend's pickup truck when it stalls on a hill. You jump out, get behind the truck and push with all your might (300 N). Still, the truck slowly rolls back down the hill. The force the truck exerts on you is:

a. greater than 300 N..
b. 300 N.
c. less than 300 N.
d. it's not possible to tell.

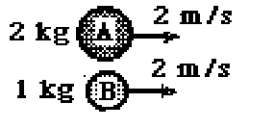
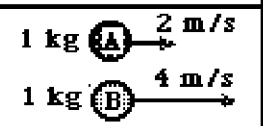
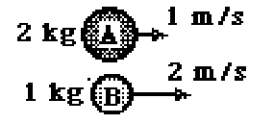
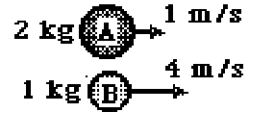
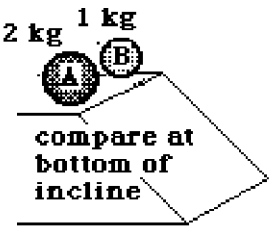


APPENDIX C

UNIT FIVE CONCEPTUAL PRE AND POST TEST

Momentum Quiz: Conceptual

For each of the situations outlined below in questions 1-4 compare (a>b, a<b, or a=b) the momentum of sphere A and sphere B. Then offer a brief explanation supporting your response.

	Situation	Comparison of Momentum	Explanation
1.			
2.			
3.			
4.			
5.			

6. _____ A rifle recoils while firing a bullet. The speed of the rifle's recoil is small because the

a. force against the rifle is small compared to the force on the bullet.
b. force is mainly concentrated in the bullet.
c. rifle has lots of mass.
d. momentum of the rifle is unchanged.

7. _____ In order to catch a ball, a baseball player moves his or her hand backward in the direction of the ball's motion. Doing this reduces the force of impact on the player's hand principally because it

a. increases the impact time.
b. decreases the impulse on the glove.

37

c. decreases the change in momentum of the ball.
d. all of the above

8. _____ A 1.0 kg chunk of putty moving at 1.0 m/s collides and sticks to a 5 kg bowling ball that is initially at rest. The magnitude of the momentum of the **ball and putty** after collision

a. 0.0 kgm/s. b. 1.0 kgm/s.
c. less than 1 kgm/s. d. 5.0 kgm/s.

.

9. _____ A golf ball moving forward with a momentum of 1.0 kgm/s strikes and **bounces** backward off a heavy bowling ball that is initially at rest and free to move. The momentum of the **bowling ball** after collision is

a. less than 1.0 kgm/s. b. more than 1.0 kgm/s.
c. 1.0 kgm/s. d. not enough information provided

10. _____ Padded dashboards in cars are safer in an accident than non-padded ones because they

a. increase the impact time. b. decrease the impulse on the occupant.
c. increase the force on the occupant. d. all of the above

11. _____ A bug collides with the windshield of a car traveling down the highway. Which experiences the greater change in **momentum**?

a. it depends on the initial velocity of the bug b. the car
c. the bug d. both experience the same change

12. _____ The momentum of an object can be calculated by multiplying the mass of the object by its

a. acceleration b. velocity
c. impulse d. time

13. _____ The greatest change in momentum will be produced by a

a. large force acting over a long time b. small force acting over a short time
c. large force acting over a short time d. small force acting over a long time

14. _____ Impulse can be represented by

a. $\Delta v/\Delta t$ b. $F\Delta t$
c. mv d. m/v

15. _____ When a golf club hits a golf ball, the change in momentum of the ball is _____ the change in momentum of the club

a. equal to b. greater than
c. less than d. the square root of

16. _____ Lexi is standing on roller blades and is holding a heavy medicine ball. If she throws the medicine ball horizontally to the right, what will be her resulting motion?

a. to the right b. to the left

c. no motion d. upwards

APPENDIX D

LIKERT PRE AND POST SURVEY

Unit Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

* Required

1. **Your Student Number** *

Mark only one oval.

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20

2. **I like School** *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

3. **I get good grades in school** *
Mark only one oval.

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

4. **I like science classes** *
Mark only one oval.

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

5. **I do well in science classes** *
Mark only one oval.

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

6. **I like the labs we do in science class** *
Mark only one oval.

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

7. **I feel like I try my best during science class** *
Mark only one oval.

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

8. **I feel that the labs we do in science class help me understand Science** *
Mark only one oval.

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

9. **I am bored a lot in science class** *
Mark only one oval.

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

10. **I feel engaged in science class** *
Mark only one oval.

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

11. **I am a competitive person** *
Mark only one oval.

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

12. **It's fun to design and build things** *
Mark only one oval.

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

13. **I like working in a group** *
Mark only one oval.

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

14. **I feel more engaged in this science class than I do in other science classes** *
Mark only one oval.

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

15. **I enjoy our competitive labs (Junk Box Wars) more than traditional labs** *
Mark only one oval.

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

16. **I feel more confident about my science skills now than I did at the start of the year** *
Mark only one oval.

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

17. **Do the labs we do in class help you understand things for the test? Why or why not?** *

Powered by Google Forms

APPENDIX E

SAMPLE JUNK BOX WAR RUBRIC

Junk Box Wars Rubric: Go Speed Racer!

	Excellent	Good	Satisfactory	Needs Improvement	
Planning	Students demonstrated an understanding of event rules and developed strategies for a successful project.	Students demonstrated a basic understanding of event rules and the developed some strategies for a successful project.	Students required assistance to understand event rules and develop strategies for a successful project.	Students did not demonstrate an understanding of event rules and failed to develop strategies for a successful project.	
Use of Class Time	Students were on task during the entire project	Students were on task but needed teacher redirection	Students were on task, but needed multiple teacher redirection	Students were not on task or needed constant teacher redirection	
Team Work	Team focused on the task and everyone was allowed to contribute to final product	Team focused on the task and allowed everyone to contribute most of the time.	Team had to be reminded to stay focused on the task and involve all group members.	Team did not stay focused on the task and limited the involvement of some group members.	
Materials	Students selected appropriate materials and used creativity to modify them to work better.	Students selected appropriate materials and an attempt was made to modify them to work better.	Students selected inappropriate materials for the project or failed to make modifications.	Students selected inappropriate materials and failed to make modifications	
Analysis	Students were able to identify strengths and weaknesses of the device and recommend modifications.	Students were able to identify some strengths and weaknesses of the device and recommend some modifications	Students were able to identify a limited amount of strengths and weaknesses of the device, but recommended modifications were limited or flawed.	Students failed to identify strengths and weaknesses of the device and recommend modifications.	

Function	Device functioned extremely well based on the testing conditions	Device functioned well based on the testing conditions	Device met design requirements, but did not perform well under testing conditions	Device had fatal flaws that caused it to function poorly or did not allow testing.	
Creativity	Was extremely creative and presented with originality; used a unique approach that truly enhanced the project	Was creative at times; thoughtfully and uniquely presented	Added a few originals touches to enhance the project but did not incorporate it throughout	Little creative energy used during this project; was bland, predictable and lacked "zip"	
Distance Traveled	Self-propelled; traveled greater than 4 meters	Self-propelled; traveled 3-4 meters	Self-propelled; traveled 2-3	Self-propelled; traveled 0-2 meters	
Final Design	Design meets or exceeds desired objectives	Design meets desired objectives	Barely capable of achieving desired objectives	Not capable of achieving desired objectives	
Speed	Top speed Go Speed Racer Go!	Middle 2 speeds Go!	Low 1 speed Go turtle Go!	Was your car in slow motion?	
Total					