

THE EFFECT OF A GAMIFIED LEARNING SEGMENT IN A HIGH SCHOOL  
CONCEPTUAL PHYSICS CLASSROOM ON STUDENT ENGAGEMENT,  
MOTIVATION, AND MEASURES OF LEARNING

by

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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 2019

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## ACKNOWLEDGEMENT

Firstly, I would like to express my appreciation and gratitude for the Master of Science in Science Education (MSSE) program at Montana State University. This has been an incredible experience for me and I have grown a lot as an educator as a result of my classes, as well as participating in action research. An enormous thank you to Diana Paterson for her help with my capstone and getting me registered for classes, since I always seemed to have trouble. She also always went above and beyond to help answer my questions. Thank you to Marcie Reuer, Greg Francis, and Lindsay Hall. Your valuable feedback kept me on track and was crucial to completing my first action research project. All the MSSE staff's kindness and support throughout this program made me feel a part of the campus, even when a thousand miles away.

Secondly, thank you to all the support from my new school, Pinnacle High School. They allowed me the freedom to conduct research with my students and always asked if there was anything they could do to help me. Thanks to all my students this year. I was able to better understand your academic needs over the course of this project and you were well-spirited whenever I asked you to fill out another survey or change up the routine so I could collect some data.

Finally, I cannot thank my friends and family enough for their love and encouragement. I appreciate the understanding when I had to give up time in order to work on grad school classes. I especially want to thank my fiancé, Katelyn. You have always been there for me, cheered me on, and most importantly, loved me. You helped to

motivate me when I was feeling stuck and served as my biggest fan. I am incredibly grateful and I cannot wait to spend the rest of my life with you by my side.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND .....1

2. CONCEPTUAL FRAMEWORK .....3

3. METHODOLOGY .....10

4. DATA AND ANALYSIS .....16

5. INTERPRETATION AND CONCLUSION .....29

6. VALUE .....31

REFERENCES CITED .....35

APPENDICES .....38

    APPENDIX A Institutional Review Board Exemption .....39

    APPENDIX B Force Concept Inventory .....41

    APPENDIX C Time On-Task Data Collection Chart .....51

    APPENDIX D Student Perception Survey .....53

    APPENDIX E Interview and Focus Group Protocol .....57

    APPENDIX F Classroom Assessment Techniques .....59

LIST OF TABLES

1. Data Triangulation Matrix .....	11
2. Average Time On-Task Normalized Gains .....	17
3. Muddiest Points CAT Results .....	19
4. Minute Paper CAT Results .....	25

## LIST OF FIGURES

1. Average Percent Time on-task of Pre- and Post-treatment Class Periods .....	16
2. Results for Treatment Periods Pre- and Post-treatment on Survey: “How Much Attention Did You Give Yesterday's Lesson?” .....	17
3. Results for Treatment Periods Pre- and Post-treatment on Survey: “During Yesterday’s Lesson, My Mind Wandered.” .....	18
4. Results for Treatment Periods Pre- and Post-treatment on Survey: “Yesterday’s Lesson in Physics Was Engaging.” .....	18
5. Results for All Periods Pre-treatment on Survey: “What Motivates You the Most to Do Well in Physics.” .....	21
6. Results for All Periods Post-treatment on Survey: “What Motivates You the Most to do Well in Physics.” .....	21
7. Results for Control Period Post-treatment on Survey: “What Motivates You the Most to do Well in Physics.” .....	22
8. Results for Treatment Periods Pre- and Post-treatment on Survey: “If Mr. Rider Asked Me to Explain Exactly What You Learned Yesterday, I would Be Able to Explain It.” .....	24
9. Results for Treatment Periods Pre- and Post-treatment on Survey: “Yesterday’s Lesson Sparked My Interest in the Physics Concept We Learned.” .....	24
10. Results for Treatment Periods Pre- and Post-treatment on Survey: “Yesterday’s Lesson Motivated Me to Keep Learning About the Physics Concept We Learned” .....	26
11. Frequency of Scores on the Force Concept Inventory Before the Treatment .....	27
12. Frequency of Scores on the Force Concept Inventory After the Treatment .....	28

## ABSTRACT

Students often struggle learning physics concepts, in large part due to the lack of engagement and motivation in many science classrooms. Students who are focused in and engaged with the material tend to believe that they understand the concepts better than those who are uninterested. This study primarily investigated the effect of gamifying a learning segment using Classcraft on student engagement, motivation, and perception of physics. The study also examined the effect of gamifying different portions of the instructional sequence, as well as the effect on performance on formative and summative assessments. Students played Classcraft while learning about Newton's 2<sup>nd</sup> Law while their time on-task was observed. Then, they answered survey questions, participated in an interview, or participated in a focus group to share their experiences. The results indicated that playing Classcraft while learning about physics did increase student time on-task and perception of engagement. However, what motivated students remained largely unchanged. Lastly, there was also not a substantial difference in direct measures of learning on summative assessments but there did appear to be a difference on formative assessment performance.

## INTRODUCTION AND BACKGROUND

This school year, I started my fourth year teaching at a new school in Phoenix, Arizona: Pinnacle High School. This school is relatively new (built in 2000) in the Paradise Valley Unified School District (PVSchools). It is a large, relatively affluent, suburban school which enrolls approximately 2,700 students, grades 9-12. In the 2015-16 school year, the student population had the following demographic breakdown (National Center for Education Statistics, 2016):

- 52% male and 48% female
- 2% black, 12% Hispanic, 4 % Asian, and 79% white, and 3% multi-racial
- 7% eligible for free and reduced lunch

I taught five sections of freshman-level conceptual physics, which was a brand-new experience for me as this was my first time teaching freshman and my first time teaching physics to this level of students. Previously, I taught two years of honors physics to primarily juniors and seniors in Denver, Colorado. I had 149 physics students this year and the demographics largely matched the school's as a whole: male, female, and the majority are white with a low percentage of students of color. I also had one inclusion class, taught with the aid of a paraprofessional, which contained six students with special needs.

PVSchools restructured their science sequence to be physics first, which requires all freshman to take conceptual physics (honors or regular) when they enter high school. Pinnacle is their flagship school which has had the freshman physics classes since it opened. As the students are, in general, concurrently enrolled in Algebra I, students do

not have the math background in order to do the same types of problems that are common among older students. The main focus is on building the concepts of physics and getting students to think critically, improve graphical analysis skills, and increase access to physics education. While there are some clear benefits to having freshman take physics, there are definitely some pushback among students and parents alike, due to student level of maturity and experience with mathematics.

In my first four years of teaching, I have noticed that engagement in science curricula is generally low; students will check all the metaphorical boxes in order to earn a desired grade. This observation did not only apply to my former students back in Colorado, but my current students as well. I believe they are largely focused on grades and how they will affect their chances on getting accepted to their desired college or university, scholarship opportunities, etc. instead of the actual learning of the material. Students don't realize how fun learning physics can be. Furthermore, I observed that many science teachers don't make their classes as fun as they could be. Students have a much higher chance of being engaged with the material in and outside the classroom if they are having fun throughout the learning process (Willis, 2007). Thus, I will address the following research question over the course of this study: How does embedding a gamified learning segment in high school physics classes influence student engagement, motivation, and perception of physics? A learning segment is a set of successive lessons which have a common instructional focus (Stanford Center for Assessment, Learning, and Equity, 2018). Additionally, I will address four sub-questions: 1) Are different portions of the instructional sequence more conducive to embedding gamification than

others?, 2) Is there an effect on student attitudes of enjoyment and entertainment in learning physics by participating in a gamified learning segment?, 3) Is there an impact on direct measures of learning, such as formative and summative assessment performance?, and 4) Are students more willing to extend their learning of physics beyond the curriculum after participating in a gamified learning segment?

### CONCEPTUAL FRAMEWORK

This literature review will look at the topic of gamified learning through a few different lenses, beginning with what motivates students. Today's students live in a very different world when compared to students even ten years ago; thus, what motivates and applies to them may differ as well. Next, gamification is a broad topic with numerous variations and applications (Hamari, Koivisto, & Sarsa, 2014). The common elements of gamified learning will be addressed. Lastly, the effect, if any, on student outcomes including motivation, engagement, and performance will be discussed.

Students today experience the world much differently than they did even a decade ago. They have grown up with access to technology and have a different attitude to learning than students of previous generations (Kiryakova, Angelova, & Yordanova, 2013). Students tend to be more motivated working on projects or assignments that include technology since it is viewed as much more engaging and fun. However, students are still motivated by a lot of the same core factors, according to Muntean (2011):

Motivation, at its core, can be caused by couples of opposites like pleasure/pain, hope/fear, and social acceptance/rejection. If for example a student is able to solve a problem but has no motivation to do it, he will not do so. Once his social reputation is at stake or he is conscious of the fact that he might get a small grade, the motivation, either positive or negative will determine him to solve the problem (p. 324).

Educators can tap into these intrinsic motivators in order to increase engagement in the course content. However, if a student ceases to be motivated by such intrinsic factors alone, then educators must determine what other motivators will aid in the learning process. This is actually a very common issue experienced by educators; students lack engagement, motivation, and active participation in the learning process (Kiryakova et al., 2013). Extrinsic motivators such as rewards for accomplishments can potentially increase buy in for students who lack intrinsic motivation. However, the goal for teachers is usually not to replace intrinsic motivation for extrinsic among students. The aim is to supplement intrinsic motivation in order to increase performance by offering an additional means of motivation (Muntean, 2011). Fogg (2009) believes that this supplementation can lead to positive behavioral changes in students. He states that, “[students] who have high ability but low motivation need to have motivation increased so they cross the behavior activation threshold.” (p. 4). The Fogg Behavioral Model describes how three principles influence our ability to change behavior: motivation, ability, and triggers. For example, a person’s ability is reliant on the simplicity of a particular task. Simple tasks depend on multiple factors: time, money, physical effort, etc. This is a “function of the scarcest resource at the moment the behavior is triggered”, meaning that the timing is also a major factor in changing a behavior. A trigger can include a spark of inspiration, a facilitator which simplifies a task, or a signal which indicates that a behavior is appropriate (Fogg, 2009). For someone to alter their behavior, all three principles must be sufficiently present. Thus, if the goal of a teacher is to change

behavior of a student or group of students, they can attempt to increase motivation, assuming the ability is there and a trigger is present.

Technology is entrenched in student culture. Teenagers today often have trouble putting down their phones, laptops, or tablets since these devices are so engaging to them. They have an expectation for their learning to be as engaging as their technology and for technology to be assimilated into the learning process (Lister, 2015). Lister claims many teachers wish to incorporate technology to tap in to student expectations of engagement. The advent of the smart phone, with innumerable notifications and applications to engage in, gives educators quite the competition with their use of technology for educational purposes

Children learn a lot about the world through playing. Whether the game play is complex or simple, or whether there is technology involved or not, it can help students in the learning process (Annetta, Minogue, Holmes, & Cheng, 2009). This is true not only for young children, but for students of all ages. Thus, incorporating game play in education can help students learn more advanced and complex skills beyond the basic level. Kiryakova et al. states that, “gamification is an integration of game elements and game thinking in activities that are not games” (p. 1). Gamified learning consists of applying game elements to the classroom. Research in this field is still fairly new and researchers are very interested in the potential for making the learning process more entertaining for students (Domínguez, Saenz-De-Navarrete, De-Marcos, Fernández-Sanz, Pagés, & Martínez-Herráiz, 2013). Many game elements can be applied to a lesson, learning segment, or unit. For instance, common game elements include: points,

leaderboards, badges, and levels (Lister, 2015). These components provide additional motivators besides grades to engage and intrigue students in the content.

Integrating game elements into non-game situations has become increasingly common (Deterding, Dixon, Khaled, & Nacke, 2011). Definitions of gamification have been difficult to pin down since the term itself has been contested within the game industry and game studies community (p. 9). The authors make the distinction that gamification specifically relates to games and not play. The intent behind games for entertainment and games for education is entirely different and thus, gameful interactions must be brought forth by using carefully chosen game elements (p. 12). Deterding believes that the best practice for implementing gamification into non-game contexts is to ensure that it involves game design, elements but not “full-fledged games”, and characteristics for games but not play. His ideas could, in theory, expand to any sort of game, regardless of the media. The educational role-playing game, Classcraft, attempts to tap into game design, game elements, and game characteristics (Young & Young, 2019). This company aims to create a modern learning environment where the use of “technology, games, and story-telling” allows for the content to be more culturally relevant. Young claims using the site in the classroom will increase engagement, emphasize cooperation, and aid in classroom management. Students create an avatar, earn experience points, lose health points, and can utilize power-ups all while learning the content

Batson & Feinberg (2006) claim that “overall, it is becoming more and more important to supplement traditional education with e-learning games that engage and

motivate students” (p. 34). The authors believe that when students use games to aid in their learning, they actively seek learning rather than passively allow learning to happen. They further contend that learning in the form of a game allows students to become more personally invested which allows for higher retention of the learning objectives (Batson & Feinberg, 2006, p. 42). This investment is due to gamified learning, which hits on key player motivations: cognitive, emotional, and social (Domínguez et al., 2013). This idea is expanded upon by Tan & Soc Lingam (2015); they state that “It is essential that the challenges, activities and rewards are and carefully planned so that engagement is not merely in ‘fun’ or ‘socializing’ activities” (p. 7). Thus, although gamified learning appeals to socializing, it is important to pick activities that also focus on team building and collaboration (Tan et al., 2015).

The majority of the literature suggests that there is an increased level of student motivation and engagement once game elements are applied to education with a few limitations. For example, Lister analyzed 19 different studies on gamification at the post-secondary level. She found that 12 out of 19 studies (~63%) saw a positive impact of motivation (p. 12). This is consistent with another analysis of 24 studies on gamification (Hamari et al., 2014). The authors found that 15 out of 24 studies (again about 63%) saw positive results with regard to motivation and engagement. Many of the studies were optimistic regarding student behavioral outcomes. For instance, Kiryakova et al. (2013) claimed that gamification is effective in positively changing behavior. The change also leads to an improved attitude, including motivation and engagement, resulting in improved understanding of the content as well as better learning conditions (p. 4). This

idea attempts to explain how gamification increases student understanding; students have an improved learning environment with a higher level of motivation which, in turn, leads to increased performance and comprehension. This model for student achievement and behavioral outcomes is corroborated by Hamari et al. (2014), “gamification can be seen to have three main parts: 1) the implemented motivational affordances, 2) the resulting psychological outcomes, and 3) the further behavioral outcomes” (p. 3026). These findings hint that gamification could have both a short-term and long-term effect on student performance. Additionally, Hong & Masood (2014) concluded that, “...gamification teaching method did show better potential in raising students’ engagement in the classroom when compared with the conventional teaching method” (p. 3771). The author found that there was a statistical difference between conventional and gamified teaching methods.

Although many studies agreed that gamification does increase student engagement and motivation leading to more positive behavioral outcomes in the classroom, there were also some mixed results. Tan & Soc Lingam (2015) found that 90% of the participants who used the GameLead application (Tan, 2014) as a learning tool in a business class thought that the game helped them to learn and think deeply about real-world applications of the content. Also, 80% of the participants found the game to be engaging. However, only 54% of the respondents felt that the “rewards were appealing” and 72% would “complete the tasks even without the rewards”. Hamari et al. (2014) showed similar results. The studies the authors analyzed indeed found that most found gamification had positive results, yet a few concluded these results might not continue to

be positive in the long term. Hamari argues this could be due to a “novelty effect” since gamification is usually new for students participating. Additionally, Annetta et al. (2009) did not find significantly different results post intervention for student learning when comparing traditional vs. gamified lessons. Lastly, Domínguez et al. (2013) found mixed results. Most students had a positive experience with gamified learning and the group who played the game scored higher on all practical application questions, but scored lower than the traditional learning group on both a written exam and participation in the class (p. 20). Consequently, some portions of gamified instruction could be detrimental to student learning.

Deterding (2014) also explains some problems associated with gamification. For example, leaderboards and competition can induce pressure and anxiety, as some people respond well to competition while others do not (p. 308). Additionally, true games promote autonomy meaning players can choose to play or cease to play the game (p. 309). Deterding continues to express his concern about using gamified systems in an environment which is compulsory (such as school), since it can be seen merely as a tool to encourage obedience (p. 309). This perception decreases motivation, enjoyment, and performance. The author also suggests that since games have sets of rules, norms, and goals, there is also the potential for players to game the system (p. 310). This means that their focus is now on winning and not on learning, which contributes to the problem gamification is purporting to solve. Lastly, players could be turned off the game if they are too embarrassed to play, for fear of not doing well and social rejection. All these are counter to the idea that game elements in education will increase engagement and

positive behaviors. Although the author articulates these concerns, he also remedies some of his own scrutiny. Deterding explains that a careful and intentional game design is able to combat user anxiety, perception of manipulation, and ability to game the system (p. 320). These critiques will be important to consider when designing and embedding gamified learning into any educational setting.

In summary, gamification in education is an effective way to increase both motivation and engagement among students within a specific content area (Kiryakova et al., 2013). Many studies found that students enjoyed incorporating games into the learning process (Batson & Feinberg, 2006; Hong & Masood, 2014; Tan & Soc Lingam, 2015) and felt that the games helped them to learn. Additionally, students appreciate the instant feedback which stimulates further learning (Muntean, 2011). However, gamification does have limitations (Deterding, 2014) and many mixed findings of success (Hamari et al., 2014). Some studies have found statistical difference between traditional teaching and gamified learning (Hong & Masood, 2014) and others found no statistical difference (Annetta et al., 2009). Thus, gamification in education requires continued research regarding its effectiveness (Domínguez et al., 2013). Most studies looked at the results from post-secondary students so the effectiveness may differ when analyzing the results from students at the secondary level.

## METHODOLOGY

The purpose of this study was to determine if there was an effect on student engagement, motivation, and measures of learning by implementing a gamified learning segment throughout the conceptual physics curriculum. Moreover, the study was to

determine if embedding gamification into particular sections of the instructional sequence was more effective than others. Lastly, to determine if there was an effect on student attitudes of enjoyment and entertainment by having different sections of a learning segment gamified. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

The following triangulation matrix (Table 1) summarizes all of the data collection instruments used:

Table 1  
*Data Triangulation Matrix*

Research Question	Qualitative	Quantitative
How does embedding a gamified learning segment in high school physics classes influence student engagement, motivation, and perception of physics?	- Student perception survey - Student interviews - My own observations of each class and how their engagement and motivation have changed (if at all)	- Time on task data - Performance on FCI - Performance on summative assessment
SQ. 1: Are different portions of the instructional sequence more conducive to embedding gamification than others?	- Student perception survey	- Performance on FCI - Performance on summative assessment - CATs (muddiest point and minute paper)
SQ. 2: Is there an effect on student perception and attitudes of learning physics by participating in a gamified learning segment?	- Student perception survey - Student interviews - Student focus group involving a small group	
SQ. 3: Is there an impact on direct measures of learning, such as formative and summative assessment performance?		- Performance on FCI - Performance on summative assessment - CATs (muddiest point and minute paper)
SQ. 4: Are students more willing to extend their learning of physics beyond	- Survey question asking students about their interest	

the curriculum after participating in a gamified learning segment?	in going deeper into physics concepts - Student interview with one or two students to get an in-depth insight into their interest in physics concepts post-treatment - Student focus group	
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In my experience teaching physics, the forces unit is broken down as follows: 1) identifying forces, drawing free-body diagrams, and introduction to the force equation (Newton's 2<sup>nd</sup> Law), 2) more complex calculations using the force equation, introduction to types of friction, and 3) Newton's third law and multi-body problems. After considering which segment would be conducive to gamified learning, I decided to do my treatment specifically on Newton's Second Law. Since it was a conceptual physics class, I focused largely on games that reinforced concepts of forces and their relationship with mass and acceleration. The game elements that I implemented involved the educational game platform, Classcraft (Young & Young, 2019), which allows students to create an avatar, gain experience points, lose health points, compete against each other, and use power ups to earn privileges in class.

When measuring student performance on assessments, it is important to make sure classes have equivalent understanding of background material when comparing before and after treatments (Annetta et al., 2009). This was done by taking the mean report card grades for each class and normalizing the grades; since grades were not statistically different for each class, the classes were considered to be equivalent (Annetta et al., 2009; Domínguez et al., 2013). In addition to grades, I also gave the Force Concept Inventory (FCI) as a pretest which was used to ascertain a baseline on student

understanding of forces (Swackhammer, 1992) (Appendix B). The FCI also served as posttest which provided evidence to demonstrate the effect of my treatment on student measures of learning. This data was represented by a histogram and I performed an analysis of variance (ANOVA) with an alpha level of 0.05. Additionally, I disaggregated the data and analyzed different sub groups using a paired t-test, also with an alpha level of 0.05. Once different classes were established to be equivalent, students were given their separate treatments: conventional/traditional teaching methods or gamified learning (Annetta et al., 2009; Domínguez et al., 2013; Hong & Masood, 2014).

As my students began Newton's 2<sup>nd</sup> law, I showed my students Classcraft and explained the rules to them. The platform has video tutorials to show students, which explains everything they need to know and how to use it within the class. We took a day to explain what Classcraft was and I allowed students to set up their avatars. I also explained to them what sorts of behaviors would result in rewards and punishments. After students were comfortable using the platform and how I was going to use it in class, I integrated it into my physics curriculum for the treatment classes. For example, students participated in choose-your-own-adventure style quests to be presented with the material, in addition to having the game run in the background as I taught the class as I normally would. One class had each portion of the instructional sequence was gamified (introduction to concepts, reinforcement and application of concepts, and review of concepts). For three other classes, they only received gamified learning in one of the three portions of the learning segment. Lastly, the remaining class was my control group which did not receive the treatment; they were taught using more traditional methods of

short lectures, activities, and practice problems. My treatment period lasted approximately three weeks.

Before the treatment, I established a baseline for engagement by measuring time on-task. I tracked average time on-task by randomly selecting a group of seven students in each class and organized this on a data table (Appendix C). I recorded if students were on-task in thirty second intervals for ten minutes of time. After the treatment, I measured average time on-task again for the same set of students and compared the data to their baseline. This data analyzed using a single-factor ANOVA test (alpha level – 0.05) to determine if there was a difference between class periods and a Wilcoxon Rank Sum test was used to see if there was a difference within a class period between pre- and post-treatment engagement. In addition, the normalized gains were calculated and the results were represented by a table and a bar graph.

Engagement, motivation, and attitudes were measured using a pre- and post-treatment survey (Batson & Feinberg, 2006). I administered a Likert-style, student perception survey (Appendix D) as well as conducted student interviews and a focus group (Appendix E). This was to give me a more in-depth understanding on the effect of my treatment. I gave the survey twice: before the treatment and also right after the treatment was completed. This gave me a reference of what their perception of learning physics was based on my instruction so far, and compare it to after participating in the treatment. All students were given the survey, regardless of what class they were in or what order they received the treatment. The survey lasted approximately 10 minutes and students were encouraged to answer honestly and completely. Survey responses were

then scrutinized for emerging trends and themes. They were represented by bar graphs to compare pre- and post-treatment as well as pie charts to show the percent of students who answered in a particular way.

With regard to the interviews, I selected one student from each of my 5 sections (including a mix of students across different demographics as well as low, middle, and high-achieving students). These students were pulled aside for a quick (approximately 5 minute) interview about their experience with the gamified instruction. Their responses were recorded using the voice memo application on my iPad. Similarly, the focus group students were pulled aside for a quick (approximately 10 minute) discussion about their experience with the treatment. I pulled six students per class (two low-achieving, two middle-achieving, and two high-achieving) and we spoke about their perception of physics after the gamified lessons. These responses were also analyzed for trends and themes.

Lastly, the performance on the FCI, summative assessments, and formative assessments (Appendix F) gave me an indirect measure of engagement and motivation to learn physics. Classroom Assessment Techniques (CATs) were analyzed for trends and themes and were tableted. As engagement, motivation, and perception of physics are all difficult things to measure, I believe the methods used gave me multiple perspectives (qualitatively and quantitatively) to best answer my main research question and sub questions. I believe that the instruments and procedures I used covered a wide range and gave me good insight into my students' thoughts about my treatment.

## DATA AND ANALYSIS

Introducing Classcraft into my classes influenced some aspects with my students and not others. Engagement in the physics content was measured using multiple pieces of evidence. The results (Figure 1) show that the average time on-task increased by relatively large margins for each of the treatment classes and by a much smaller margin for my control class ( $N = 35$ ).

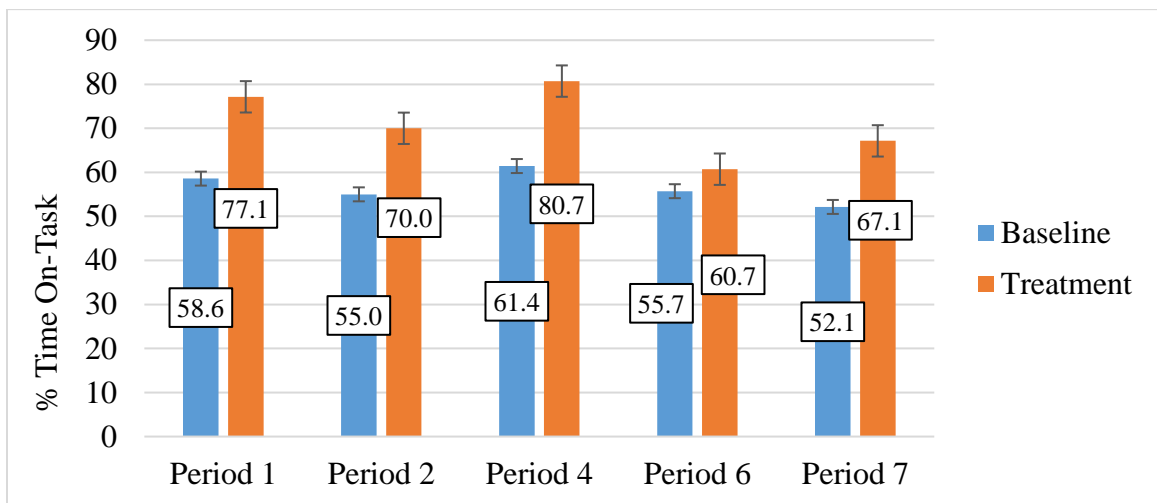


Figure 1. Average percent time on-task of pre- and post-treatment class periods, ( $N=35$ ).

In analyzing the pre-treatment time on-task, the results of a single-factor ANOVA show that there was no significant difference ( $p > 0.05$ ) between each class's average time on-task at the 95% confidence level. The post-treatment ANOVA test also showed there was no significant difference ( $p > 0.05$ ) between the classes. However, performing a Wilcoxon Rank Sum Test shows that there was a significant difference between the pre- and post-treatment average time on-task, at the 95% confidence level for three out of the four treatment classes. Period 2's test statistic was the same as the critical value so I was unable to reject the null hypothesis. That being said, they still increased their time on-task

by a relatively large amount (55.0% to 70.0%). Additionally, calculating normalized gains (Hake, 1998), showed how much each class increased their time on-task (Table 2).

Table 2  
*Average Time On-Task Normalized Gains, N = 35*

Class Period	Average Pre-Treatment Time On-Task (%)	Average Post-Treatment Time On-Task (%)	Normalized Gain (%)
Period 1	58.6	77.1	48%
Period 2	55.0	70.0	33%
Period 4	61.4	80.7	50%
Period 6 (control)	55.7	60.7	11%
Period 7	52.1	67.1	31%

The control class achieved the lowest gain at 11%. The normalized gains for the treatment classes ranged from 31-50%, indicating that these classes increased their time on-task by a sizable amount. This is further suggested by the responses on multiple survey questions. Students were asked using a Likert-style survey ( $N = 110$ ) several questions regarding engagement: “How much attention did you give to yesterday’s lesson?” (Figure 2), “During yesterday’s lesson, my mind wandered” (Figure 3), and “Yesterday’s lesson in physics was engaging” (Figure 4).

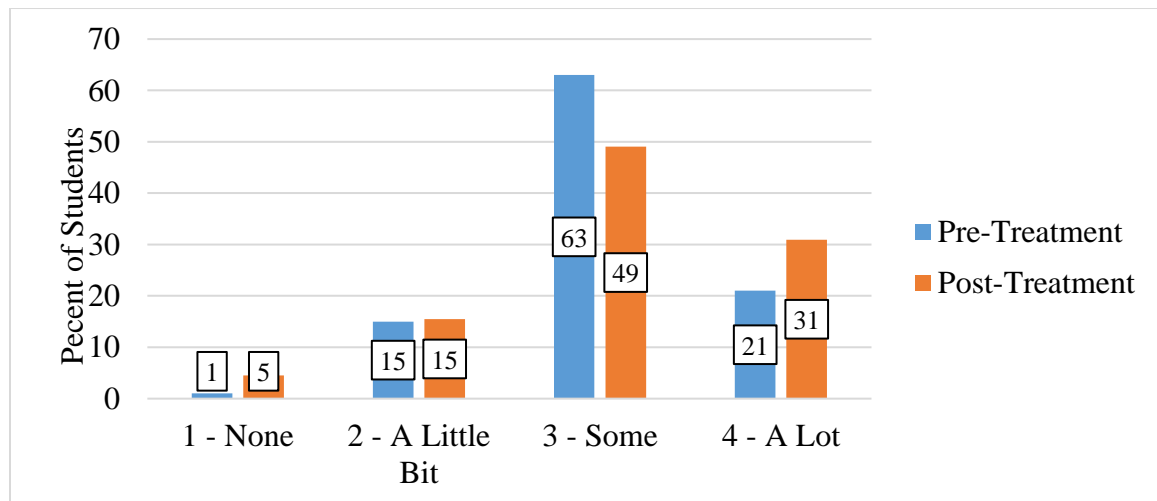


Figure 2. Results for treatment periods pre- and post-treatment on survey: “How Much Attention Did You Give Yesterday’s Lesson?”, ( $N=110$ ).

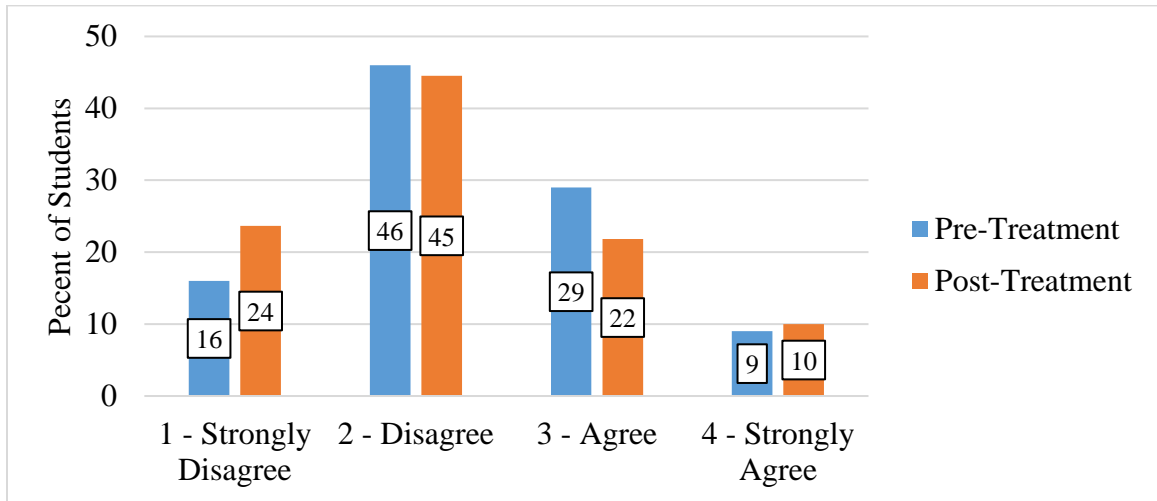


Figure 3. Results for treatment periods pre- and post-treatment on survey: "During Yesterday's Lesson, My Mind Wandered.", ( $N=110$ ).

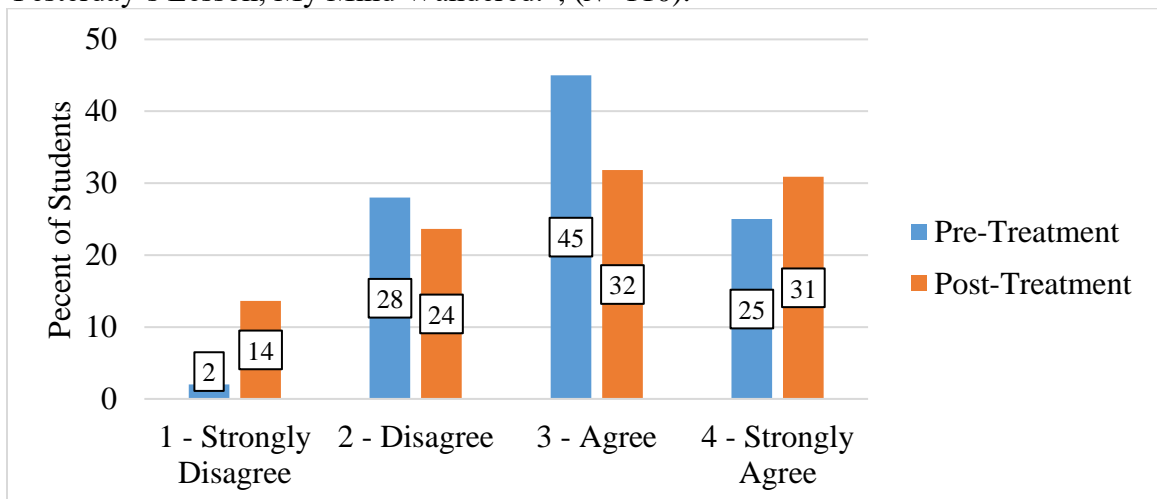


Figure 4. Results for treatment periods pre- and post-treatment on survey: "Yesterday's Lesson in Physics Was Engaging.", ( $N=110$ ).

Looking at pre- and post-treatment responses, about the same number of students disagreed and strongly disagreed about paying attention to the pre-treatment lesson compared to the treatment lesson using Classcraft. However, 10% more students strongly agreed to paying attention to the lesson after the treatment. This seemed to match with the responses to the statement, "During yesterday's lesson, my mind wandered." 7% fewer students agreed with the statement and 8% more students strongly disagreed. This

indicates that students believed they were more focused and engaged in the material that they were learning, on average. Their self-perception of engagement was partially substantiated by their responses to the statement, “Yesterday’s lesson was engaging.” Results for this question were more polarized with percent increases for both strongly agree and strongly disagree. Although some students felt they were much more engaged and others felt they were much less engaged with the treatment, my own observations indicated that the vast majority of students were generally much more engaged. Indirectly, students in the treatment periods were more engaged than the control group as shown by their responses to the “Muddiest Point” CAT. As seen in Table 3, there were more muddy points in the control class compared to the treatment classes ( $N = 136$ ).

Table 3  
*Muddiest Points CAT Results,  $N = 136$*

Class Period	% Of Students with Muddy Points	% Of Students without Muddy Points
Period 1	42	58
Period 2	51	49
Period 4	37	63
Period 6 (control)	62	38
Period 7	55	45

A large majority of the control group self-indicated that they had muddy points after the lesson on Newton’s 2<sup>nd</sup> Law. The treatment classes all had fewer muddy points, showing that they were more engaged with the lesson. Students felt in the treatment classes that the lesson was clearer, since they were more focused on the lesson while playing Classcraft.

Some changes in student motivation were observed within the treatment classes, however, the results were very polarizing. According to one student in his interview, he

stated that, “I did enjoy that through Classcraft we are able to be more interactive with the topic itself, but it's not extremely interesting either. The program itself is motivation, as well as working with a team.” Another student replied in her interview, “I really liked the game and the concept and I think that we should play it more often throughout the school year. I like the idea of a worksheet with a story and how it was sectioned off. It was like a check list.” A third student answered, “Even though it was a game, it was still pretty boring and not motivating. I don't find physics interesting at all so no matter what we do, I don't really feel motivated. All I want to do is pass.” These responses were echoed many times over when looking at the survey responses. It was pretty clear that either students felt very motivated by the game elements or not motivated at all. How the students felt about if the game elements motivated them can be summarized by one student's response: “The game pushed me to continue the ‘Quest’ and I felt challenged to complete it in as little time as I could. The game was fun and motivated me to finish it but I thought the actual physics questions were boring.” In the control class, one student responded in his interview, “[Newton's Second Law] is fairly boring, although science in general interests me so I was slightly motivated.” Many other students in the control group expressed similar notions; they were generally motivated in learning about forces or not interested at all, based on the notes, practice problems, and videos.

Students were also asked about what motivates them to do well in physics. Answers remained relatively consistent; the majority of students believed that their grade was their primary motivating factor. This was true for all students before the treatment (Figure 5), the class periods post-treatment (Figure 6), and the control class (Figure 7).

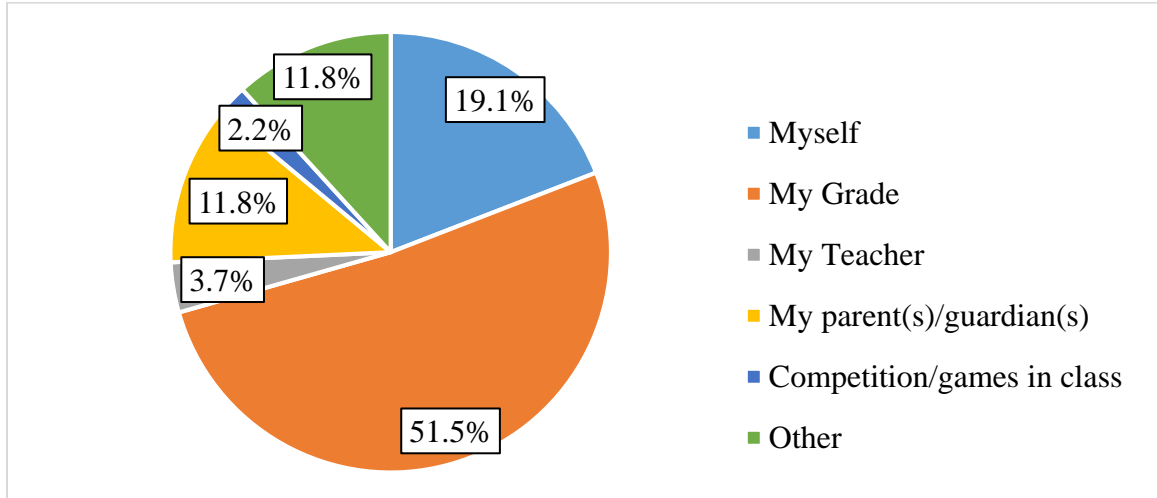


Figure 5. Results for all periods pre-treatment on survey: “What Motivates You the Most to do Well in Physics.”, (N=136).

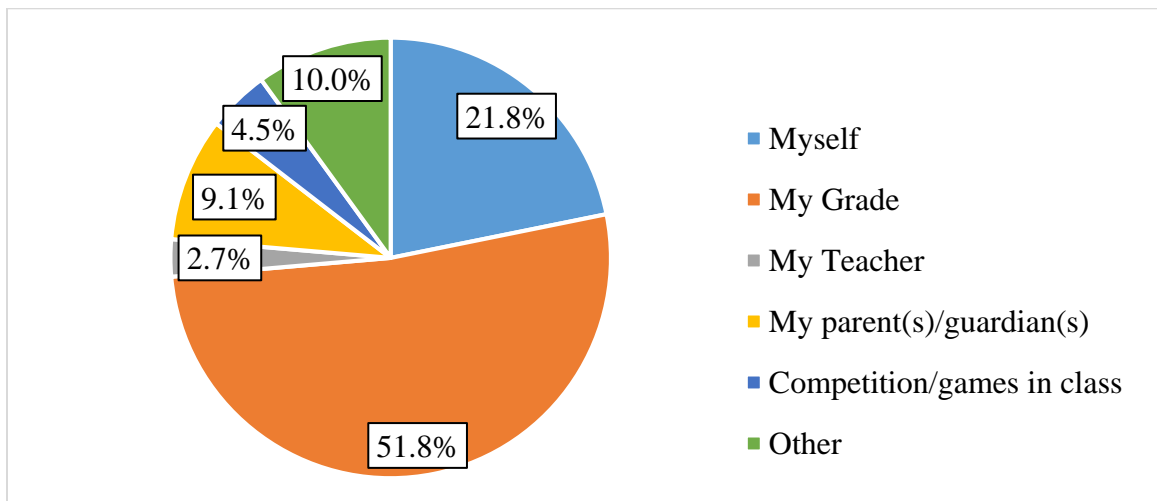
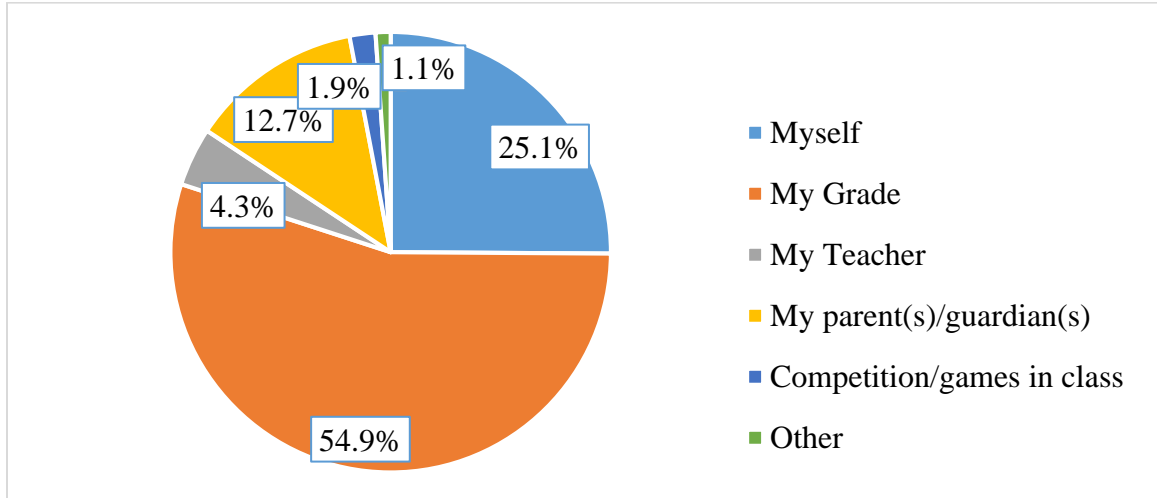


Figure 6. Results for treatment periods post-treatment on survey: “What Motivates You the Most to do Well in Physics.”, (N=110).



*Figure 7.* Results for control period post-treatment on survey: “What Motivates You the Most to do Well in Physics.”, ( $N=26$ ).

Before the treatment, the majority of students (51.5%) responded that their grade was what motivated them the most to do well in physics. The treatment did not appear to change what motivated the students since 51.8% said that their grade was the biggest motivator in the treatment periods. In the control group, about 55% believed their grade was the biggest motivator. Competition and games in class was not as strong a motivator as grade motivation, self-motivation, and parental motivation for pre-treatment classes, as well as post-treatment and control groups. However, there was a marginal increase between pre- and post-treatment classes for competition and games being a motivator with 2.2% of students stating that this was what motivated them the most in class before the treatment and 4.5% responding this afterwards. The control class decreased this response down to 1.9%.

The focus group supported these results. The students in the focus group, across each class period and regardless of whether they were a higher-performing student or lower-performing, overwhelmingly agreed that their grade is what motivated them to do

well the most. One student expressed her feeling that, “School is about grades. It doesn’t really matter if I am having fun in class or am super bored. If I have a bad grade then I am going to try and bring it up. If I have a good grade, I am going to try and keep it as a good grade.” Another student agreed, “Yeah, I love it when a teacher can make the material fun and it changes things up. But what I mostly care about is if I can get decent grades. My parents are really strict and if I don’t have good grades, I get in trouble.” The control class’ responses in their focus group matched the treatment period’s responses almost exactly. A lower-performing student replied, “I just need to make sure I pass the class so I don’t have to take it again. I don’t really care what I do to learn the material, as long as I pass. Notes and practice problems are probably the easiest way to learn it as a student and takes the least amount of work.” I did not see much difference in the responses for high, medium, or low-achieving students.

The results for a change in student perception of physics were also polarizing. For the survey questions, “If Mr. Rider Asked Me to Explain Exactly What You Learned Yesterday, I would Be Able to Explain It” and “Yesterday's Lesson Sparked my Interest in the Physics Concept We Learned”, students seemed to favor either strongly disagree or strongly agree after the treatment. Figure 8 shows student perception of being able to explain Newton’s 2<sup>nd</sup> Law and Figure 9 shows how the treatment sparked student interest in the material, compared to the baseline.

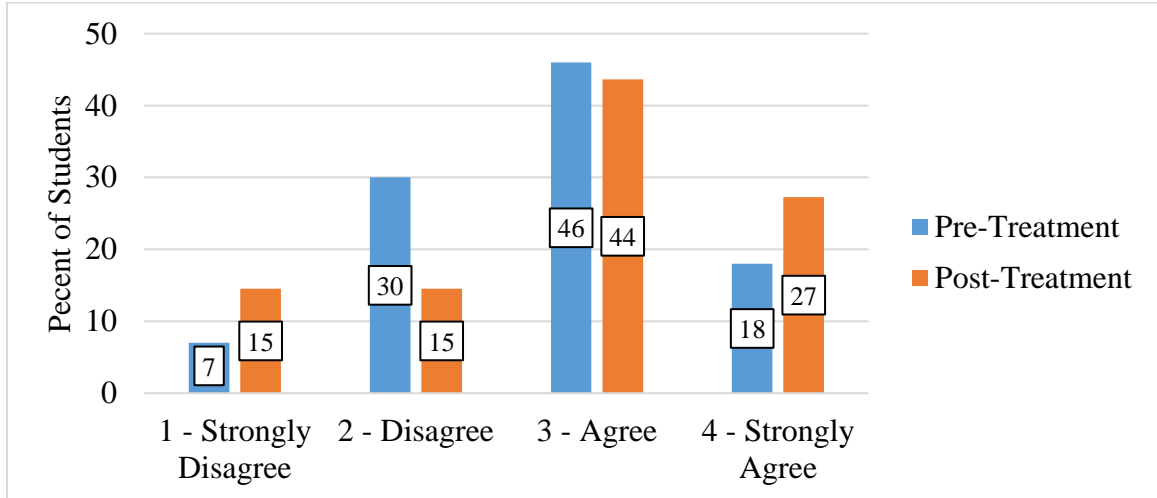


Figure 8. Results for treatment periods pre- and post-treatment on survey: “If Mr. Rider Asked Me to Explain Exactly What You Learned Yesterday, I would Be Able to Explain It.”, ( $N=110$ ).

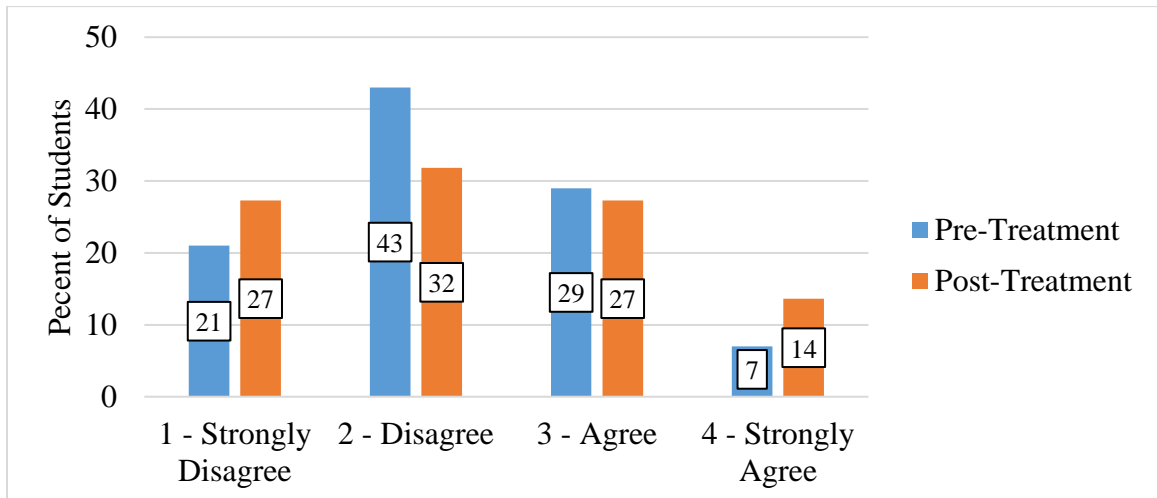


Figure 9. Results for treatment periods pre- and post-treatment on survey: “Yesterday’s Lesson Sparked my Interest in the Physics Concept We Learned.”, ( $N=110$ ).

For both survey questions, many more students either strongly agreed or strongly disagreed, a lot less disagreed, and about the same number of students agreed with the statements. That being said, many more students felt they were able to explain Newton’s 2<sup>nd</sup> law after the treatment compared to before. 71% of students either agreed or strongly agreed that they could explain what they learned the day before. This claim by the

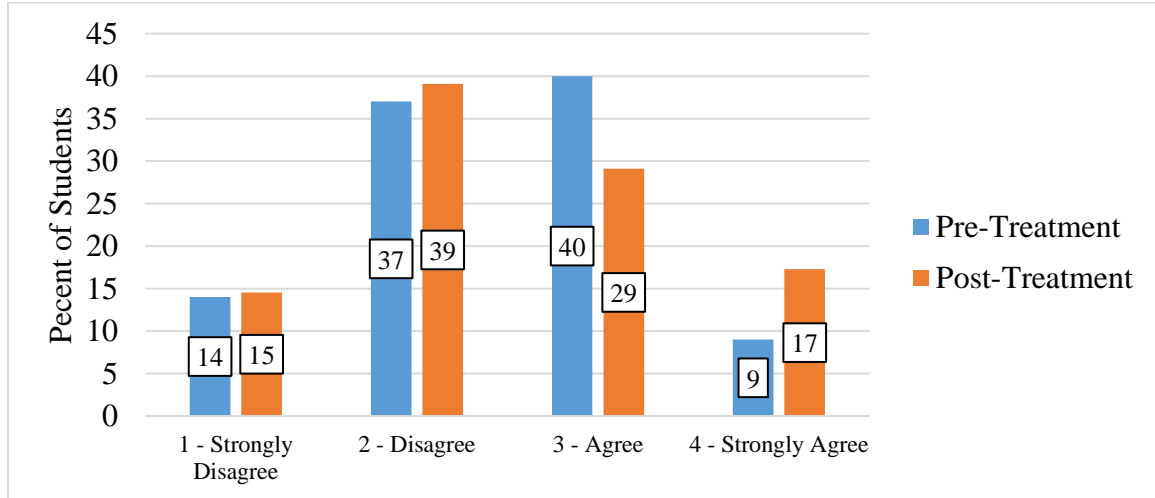
students is substantiated by their responses on the Minute Paper CAT. Students were asked to write for 60 seconds on what they learned about Newton's 2<sup>nd</sup> Law (Table 4).

Table 4  
*Minute Paper CAT Results, N = 136*

Class Period	% Correct	% Incorrect	% Unsure
Period 1	68	20	12
Period 2	55	21	24
Period 4	66	28	6
Period 6 (control)	43	32	25
Period 7	52	14	34

In each of the treatment classes, the majority of students (52-68%) were able to correctly describe Newton's 2<sup>nd</sup> Law in the CAT. In the control class, only 43% could correctly describe the law. This period also had the largest percentage of students who answered incorrectly.

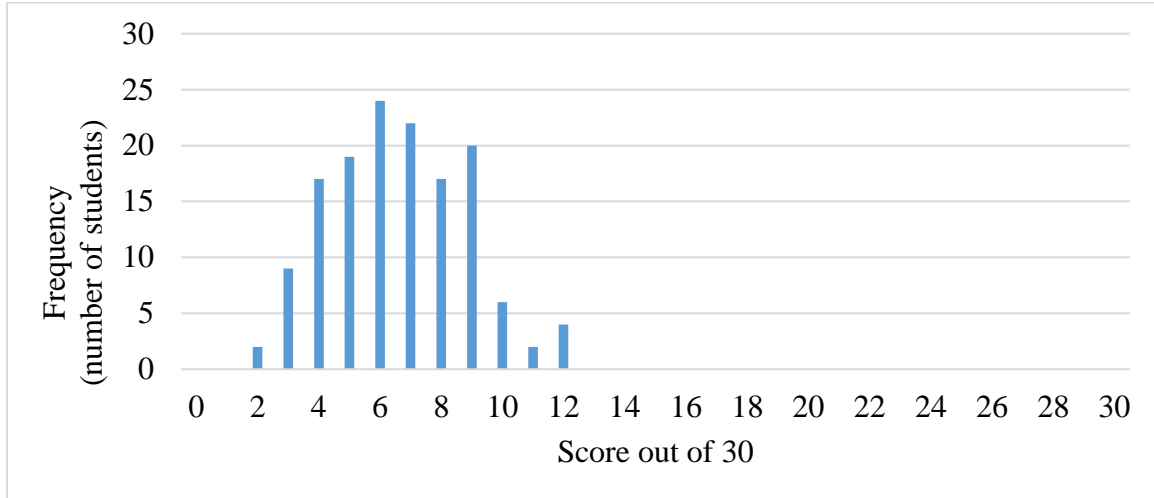
On the other hand, a larger percent of students responded that they disagreed or strongly disagreed (59%) that the treatment lesson sparked their interest. Each class period more or less had similar responses to the focus group regarding their perception of physics. Some students thought that Classcraft increased their understanding of the material and sparked their interest and others thought it made things more confusing and made them less interested. In spite of this polarization, some students did believe the treatment motivated them to extend their learning of the physics concept (Figure 10).



*Figure 10.* Results for treatment periods pre- and post-treatment on survey: “Yesterday’s Lesson Motivated me to Keep Learning About the Physics Concept We Learned”, ( $N=110$ ).

More students strongly agreed that after the treatment, they were motivated to continue learning about Newton’s 2<sup>nd</sup> Law. Despite this increase, still the majority of students (54%) disagreed or strongly disagreed that the treatment motivated them to keep learning about the material.

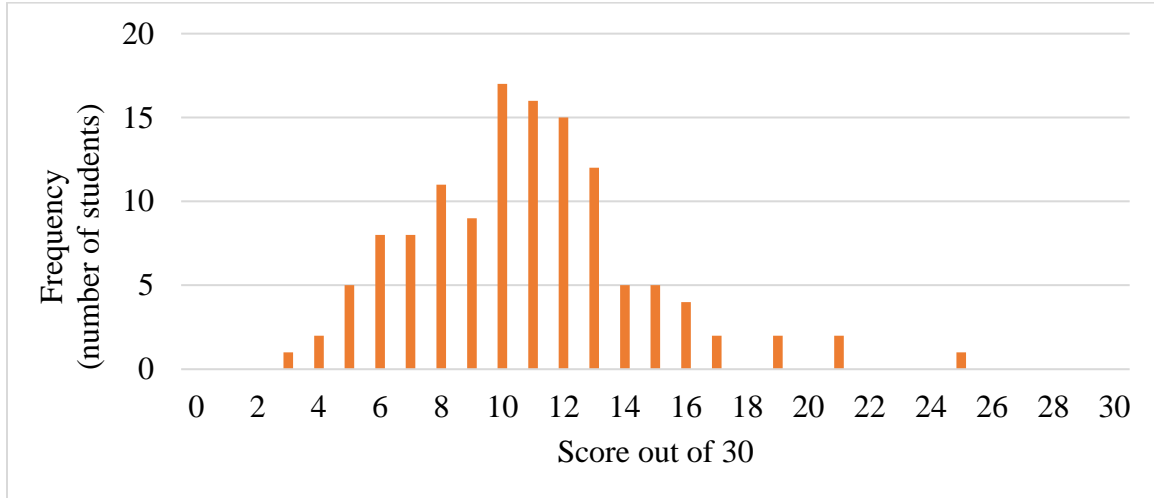
Although it is insightful to look at student perceptions and hear student ideas, engagement and motivation can also be measured by looking at direct measures of learning such as performance on summative assessments and on the Force Concept Inventory (FCI). The students took the FCI at the beginning of the school year last semester. Their individual scores out of 30 ( $N = 142$ ) are represented on a histogram (Figure 11).



*Figure 11.* Frequency of Scores on the Force Concept Inventory before the treatment, ( $N=142$ ).

This data shows a relatively normal distribution with the most common score being 6 out of 30. The mean score was 6.60 with a standard deviation of 2.21. The scores were fairly low since students had not formally learned anything about forces at this point and were basing their answer selections on their own background knowledge and intuitions. To compare the variance of the means between each class period, I used a single-factor ANOVA test. I obtained a p-value of 0.49 at the 95% confidence level, thus, I was unable to reject the null hypothesis that the mean scores for each class are the same. This told me that my classes were relatively equivalent in their background understanding of Newton's 2<sup>nd</sup> Law going into the treatment.

After the treatment, all students took the FCI again. Some students switched out of the class or moved away while others switched in. Others were not present the day I gave the FCI, so, their scores were not counted for this study ( $N = 125$ ). Their post-treatment scores are represented on the following histogram (Figure 12).



*Figure 12.* Frequency of Scores on the Force Concept Inventory after the treatment, ( $N=125$ ).

Again, the data shows a relatively normal distribution with an improved mean score of 10.73 out of 30 and a standard deviation of 3.59. This indicates a larger spread compared to the pre-treatment FCI. Comparing the results of each class period, I again used an ANOVA test. I obtained a p-value of 0.037 at the 95% confidence level which means I am able to reject the null hypothesis that the mean scores for each class are the same. The control class scored the second highest with a mean score of 11.42 out of 30 and the treatment class (period 7) which received the treatment over the course of the entire learning segment had the lowest mean score of 9.20. Although the groups were shown to have statistically different means, it appears that the treatment was not the reason for this difference. Disaggregating the data, the results show that students of color did statistically better on the FCI after the treatment compared to Caucasian students (11.7 and 10.02 respectively). A one-tailed T-test gave a p-value of 0.049, showing that on average, students of color did significantly better than Caucasian peers.

In addition to the FCI, three summative assessments regarding Newton's Second Law (a quiz, a unit exam, and a lab report) were examined for each class and averaged together. The averages ranged from 70-76%. Similar to the FCI results, it does not appear that the control group did any worse or better than the treatment classes. Instead, classes that performed better were classes that had higher baseline levels of engagement and on-task behavior as well as harder work ethic. This notion was also seen when looking at whether gamification of different portions of the instructional sequence impacted engagement, motivation, or perception of physics. For example, I did not observe a larger increase in engagement in the class which played the game the longest. My 7<sup>th</sup> period actually had the lowest baseline time on-task and lowest normalized gain in time on-task (Table 2) of all of the treatment periods, even though their lessons were gamified the most. This contributed to lower assessment averages and noticeably lower CAT performance (Tables 3 & 4)

### INTERPRETATION AND CONCLUSION

This action research project aimed to investigate the effect of a gamified learning segment in high school conceptual physics classes on student engagement, motivation, and perception of physics. It also aimed to see if different portions of the instructional sequence were more conducive to gamification and if it affected student performance on formative and summative assessments.

The time on-task data and survey responses indicated that students were more engaged in the physics content while playing Classcraft compared to the control group. Students believed they were paying more attention and their mind was more focused on

the material, although some students believed that the game made them less engaged. This was reflected in my own observations as well as results on the CATs. Students in the treatment classes appeared to be much more engaged in the material and believed they were less confused after the lesson was concluded.

Looking at more direct measures of learning, treatment classes performed better on the Minute Paper in correctly answering what Newton's 2<sup>nd</sup> Law was. Although treatment classes outperformed the control class on formative assessments, summative assessments were a more even playing field and did not yield conclusive results. The FCI also did not show an improvement for treatment classes over the control group. I believe this is because students playing the game may have retained the information more short-term, while in the long-term students were able to study on their own. The performance on summative assessments and the FCI seemed to be more reflective of individual student preparation rather than engagement during the learning segment. Students of color outperformed Caucasian students on the FCI. While it is hard to say that this correlation was due to playing Classcraft, students of color did seem particularly engaged.

Even though student engagement increased, motivation remained mostly unchanged. This was evident from the survey responses. Grades were the predominant motivator among students, along with self-motivation and motivation from parents or guardians. The game itself, while engaging, did not seem to increase student motivation or interest in the physics content. This was reiterated time again by both student interviews and focus groups. That being said, some students were extremely motivated by

the game according to their responses and my own observations. I would be interested to study which students in particular are motivated by this type of learning.

I did not find a noticeable trend regarding which portion of the instructional sequence students received the gamified lessons. Engagement, motivation, perception of physics, and performance on assessments appeared not correlated to whether the students received the treatment at the introduction, reinforcement and practice, or the review of the concept. Instead, differences among treatment classes were either small or else based more on class culture and individual work ethic.

#### VALUE

I firmly believe that students who are having fun and are interested in the material will be more likely to learn the concepts that teachers are trying to convey. Student engagement is not easy, especially in science since a lot of students view that material as something that simply does not apply to them or is not fun to learn about. This action research project gave me a lot of insight into what will motivate my students and allowed me to think of my students more as individual learners. In particular, I saw just how much what works great for some students does not work well for others. Some students thoroughly enjoyed creating their avatar, completing challenges, and earning points in order to reap the rewards. Others thought it got in the way of their learning and preferred a more traditional and straightforward approach.

Using Classcraft to gamify my instruction in order to supplement the physics material absolutely increased the engagement of my students, whether they believed that it did or not. I observed remarkably less phone distractions and redirections than I have

seen the rest of the year. Students focused their attention on their computers much more than if I would have given the same problems as a practice sheet, as seen by my control class. Undeniably, part of the engagement was due to the novelty of playing Classcraft for the first time, as was mentioned by Hamari et al. (2014). However, some students indicated that they would have loved to play all year so they could continue to cash in on the rewards. In my opinion, I would probably observe some game fatigue where students get sick of playing and would start losing focus again. I would love to see how a more long-term integration of gamification would affect student engagement. If I were to do my study again, I would begin the school year introducing Classcraft and play it in the background all year long. Students of color in particular increased their average on the Force Concept Inventory, more so than any other subgroup. I would also be interested to further study if implementing gamified learning might affect how students of color connect with the physics content.

I felt like a modern educator using Classcraft in my classes. I loved seeing my students enthusiastically cheering when they accomplished a task because they understood forces correctly. I myself had fun giving out experience points and taking away health points to my students, based on their behavior and successes. My students have never been taught in this way before so it was exciting to go through this new experience together. I want to continue this with my future students. This project has encouraged me to keep my lessons fun and to always be thinking about how I could make learning the physics concepts enjoyable. Gamification is one way to do this, however, I see it as more of a tool or a strategy rather than something that I would be doing each and

every class period. At the end of the day, students still need to find motivation within themselves, rather than rely on extrinsic factors. Also, not all learning can practically be done by playing games and students need to also be able to focus their attention on things that are less than enjoyable. That being said, I see gamified learning as a way for teachers to increase engagement in topics that are viewed by a lot of students as “boring”. My mind goes to topics such as calculations with significant figures, chemical nomenclature, and circuit analysis. All of these are critical building blocks to higher level science learning and I believe that students would have a better foundation if they had more fun learning the basics.

This project helped me to connect with my students on a different level. I saw how each student was motivated individually. Some students who were normally quiet or uninterested suddenly were having a great time learning about forces. My action research also gave me a lot of information about my students that I would have otherwise missed. It also helped me to fully appreciate data-driven instruction. Up until this point, the only data I would really look at was class averages for tests and quizzes. Now, I would like to utilize more qualitative data such as CATs and surveys. This way, I can continue to get insight into my student’s thinking and catch things I would not have realized just by looking at their assessment scores. I am now unafraid of qualitative research, as I was when starting this project. Since I had little experience with anything other than quantitative data, I was at first overwhelmed. Now, I feel comfortable with implementing and analyzing the results of qualitative data. Action research is an ongoing endeavor by the teacher to elicit student thoughts and feelings as well as identifying next steps in the

instruction. I will use action research in my classes and I believe that it will help push me to become the best science educator I can be.

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APPENDICES

APPENDIX A  
INSTITUTIONAL REVIEW BOARD EXEMPTION



INSTITUTIONAL REVIEW BOARD  
For the Protection of Human Subjects  
FWA 0000165

2155 Analysis Drive  
c/o Microbiology & Immunology  
Montana State University  
Bozeman, MT 59718  
Telephone: 406-994-6783  
FAX: 406-994-4303  
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Chair: Mark Quinn  
406-994-4707  
mquinn@montana.edu  
Administrator:  
Cheryl Johnson  
406-994-4706  
cherylj@montana.edu

MEMORANDUM

TO: Blake Rider and Walter Woolbaugh

FROM: Mark Quinn, Chair *Mark Quinn CJ*

DATE: November 26, 2018

RE: "The Effect of Gamified Learning Segments in a High School Conceptual Physics Classroom on Student Engagement, Motivation, and Measures of Learning" [BR112618-EX]

The above research, described in your submission of November 19, 2018, 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:

- (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.
- (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

APPENDIX B

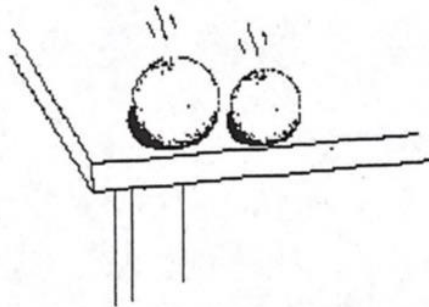
FORCE CONCEPT INVENTORY (FCI)

1. Two oranges accidentally fall out of an upstairs window of a house. One weighs twice as much as the other. The time it takes the **heavier** orange to hit the ground is:

- (A) about half as long as for the lighter orange.
- (B) about twice as long as for the lighter one.
- (C) about the same time for both oranges.
- (D) much less time, but not necessarily half as long.
- (E) much more time, but not necessarily twice as long

2. You roll these same two oranges off a kitchen table with the same speed. The **heavier** orange hits the floor at what horizontal distance from the table's base, compared to the lighter orange?

- (A) about the same distance.
- (B) about half the distance.
- (C) about twice the distance.
- (D) much closer, but not necessarily half the distance.
- (E) much farther, but not necessarily twice as far.



3. You drop an orange, not throw it, from a second story window. Which statement is correct?

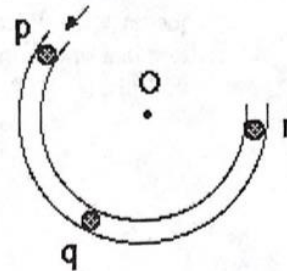
- (A) It quickly speeds up, and then falls at a constant speed until it hits the ground.
- (B) It speeds up as it falls, because the force of gravity gets stronger as it gets closer to the ground.
- (C) It speeds up as it falls, because the constant force of gravity pulls it down.
- (D) It falls because that's its natural action; things naturally tend to rest on the Earth's surface.
- (E) It falls because the force of ~~gravity~~ pulls it down and the force of gravity pulls it down.

4. A school bus and a small car crash head-on. Which applies a **larger** force on the other?

- (A) The **bus**, because it's heavier.
- (B) The **car**, because it acts like a dead weight to the bus.
- (C) Neither applies *any* force on the other; the car gets smashed up because it's in the way of the bus.
- (D) The bus applies a force on the car, but the car doesn't apply *any* force on the bus.
- (E) They both apply the same strength force on each other; the car gets smashed up because it has less substance.

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

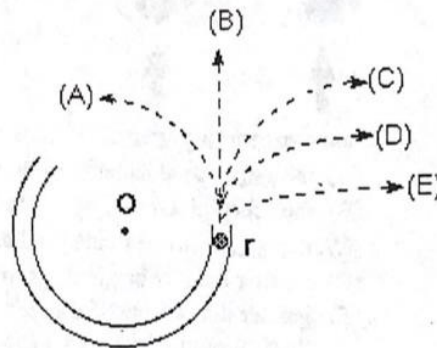
You're looking down at a horizontal game table. A very smooth metal track is fastened to the top of the table so that it can't move, as shown in the figure. (The track is shaped like an incomplete circle, and the center of the circle is marked by a dot: O.) You see a marble being shot at high speed into the track at location p, and shoot out at location r.



5. When the marble is at location q in the track, which of these forces act(s) on it? (Imagine that it's very slippery so there's no friction at all.)

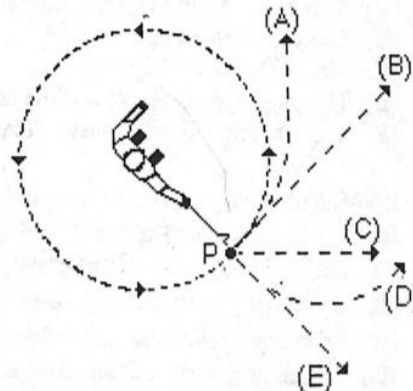
1. An **inward** force applied by the wall of the track, pointing from q to O.
2. A **forward** force in the direction that the marble is moving.
3. An **outward** force applied by the track, pointing in the direction from O to q.

- (A) None of these forces.  
 (B) 1. (Inward force)  
 (C) 2. (Forward force)  
 (D) 1 and 2. (Inward & forward forces)  
 (E) 2 and 3. (Forward & outward forces)



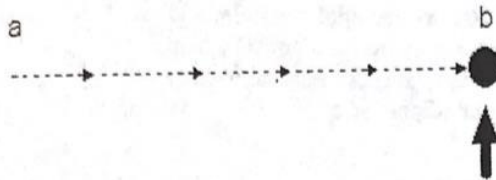
6. In the figure at the right, which path does the marble take when it shoots out of the track at location r and rolls across the table top?

7. You swing a heavy necklace -- a medallion that's attached to a string of beads -- in a circular path, horizontal to the ground. At location P in the figure, the string breaks near the medallion. Looking down from above, which path does the medallion take after the string breaks?

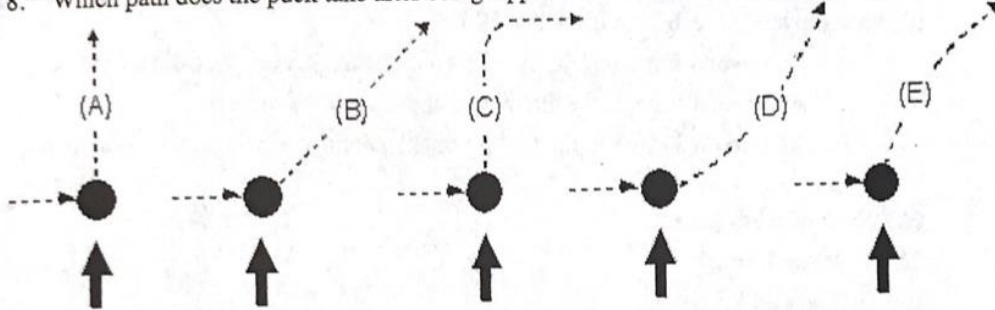


USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 through 11).

A hockey puck slides on very smooth ice in a rink at a constant speed (imagine that there's no friction) in a straight line from location **a** to location **b**. In the figure, you're looking down at the puck. When the puck reaches **b**, a player **taps** it from the direction of the heavy print arrow.



8. Which path does the puck take after being tapped?



9. In the instant just after the puck is tapped, what is its speed?

- (A) the same speed as before it got tapped.
- (B) the speed given to it by the **tap**; the original speed doesn't matter.
- (C) the sum of its original speed and the speed given to it by the tap.
- (D) smaller than its original speed, and smaller than the speed given to it by the tap.
- (E) greater than its original speed, and greater than the speed given to it by the tap, but less than the sum of these two speeds.

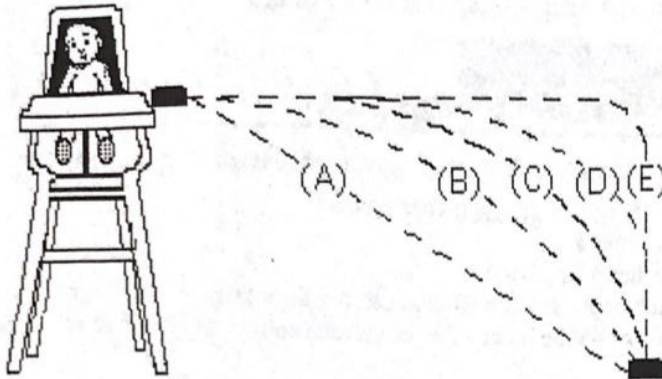
10. Look again at your answer to question 8. While the hockey puck is sliding on the smooth ice (no friction) in the rink after it's tapped, how is its speed changing?

- (A) It isn't changing; the puck moves at a constant speed.
- (B) The puck speeds up.
- (C) The puck slows down.
- (D) The puck speeds up for a while and then slows down.
- (E) The puck moves at a constant speed for a while, and then it slows down.

11. Look again at your answer to question 8. Along the no-friction path that you chose, the force(s) on the puck after it's tapped is (are):

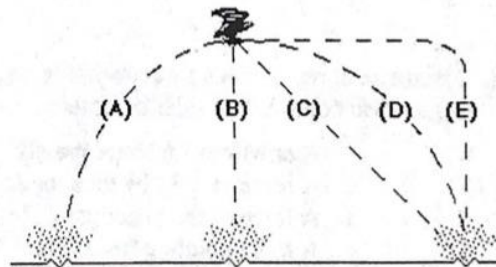
- (A) only a downward force of gravity.
- (B) a force of gravity, and the force of the tap.
- (C) a force of gravity, an upward force by the ice surface, and the force of the tap.
- (D) a force of gravity and an upward force by the ice surface.
- (E) none. No forces act on the puck.

12. A baby in a high chair slides his bowl of food horizontally off the side of his flat tray with a quick push. Which path below best represents the path of the bowl?



13. You throw a softball straight up in the air. What's the main force(s) acting on the ball after it leaves your hand?
- (A) A downward force of gravity and an upward force that gets smaller and smaller.
- (B) On the way up: an upward force that gets smaller and smaller.  
On the way down: a force of gravity.
- (C) On the way up: a force of gravity and an upward force that gets smaller and smaller.  
On the way down: a force of gravity.
- (D) Only a downward force of gravity.
- (E) No forces. The ball falls back to ground because that's its natural action.

14. You stand at the lakeshore and watch a bird carry a fish in its claws as it flies across the lake. The bird accidentally drops the fish. Which path do you see the fish take, when it drops?



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

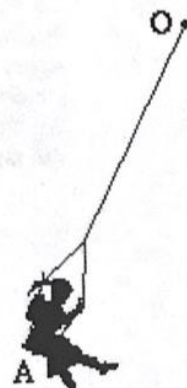
A school bus breaks down, and a car pushes it back to the garage.



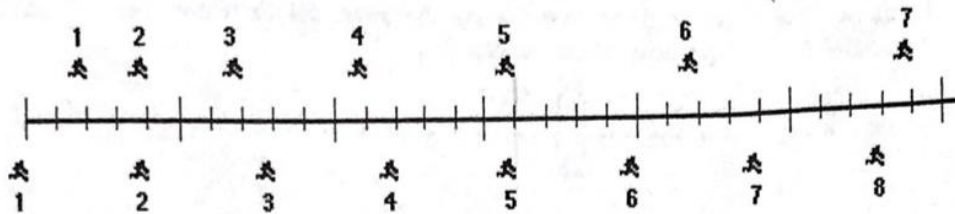
15. When the car begins to push the school bus, which applies the **larger** force on the other?
- Both apply forces of the same strength on each other.
  - The **bus**, because it's heavier.
  - The **car**. The bus applies a force, too.
  - The **car**. The bus can't apply *any* force to the car, because its engine isn't running.
  - Neither applies *any* force on the other. The bus is pushed forward because it's in the car's way.
16. After the car reaches a safe, constant speed for pushing the bus, which applies the **larger** force on the other?
- Both apply forces of the same strength on each other.
  - The **bus**, because it's heavier.
  - The **car**. The bus applies a force, too.
  - The **car**. The bus can't apply *any* force to the car, because its engine isn't running.
  - Neither applies *any* force on the other. The bus is pushed forward because it's in the car's way.
17. While you're slowly lifting a book straight upwards at a constant speed, the upward force of your hand on the book is:
- greater than the downward force of gravity on the book.
  - equal to the downward force of gravity on the book.
  - smaller than the downward force of gravity on the book.
  - equal to the sum of the book's weight *and* the force of gravity on the book.
  - the *only* force on the book.
18. The figure at right shows a girl swinging on a swing, starting at a point higher than point A. Consider the following distinct forces:
- A downward force of gravity.
  - A force exerted by the rope pointing from A to O.
  - A force in the direction of the girl's motion.
  - A force pointing from O to A.

Which of the above forces act(s) on the girl when she is at position A?

- 1 only.
- 1 and 2.
- 1 and 3.

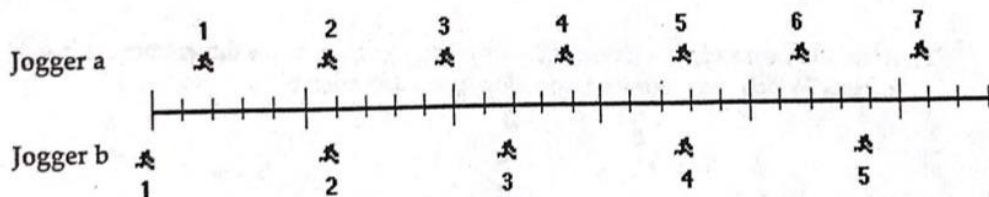


19. While you and your friend are running, your science teacher takes measurements. Later he makes this drawing. The little stick figures show where both of you are (your positions) at every second of time. You're both running to the right.



Are you and your friend ever running at the same speed?

- (A) No.  
 (B) Yes, at the 2<sup>nd</sup> second of time (that is, at the 2<sup>nd</sup> stick figures).  
 (C) Yes, at the 5<sup>th</sup> second of time (that is, at the 5<sup>th</sup> stick figures).  
 (D) Yes, at the 2<sup>nd</sup> and 5<sup>th</sup> seconds of time.  
 (E) Yes, at some time between the 3<sup>rd</sup> and 4<sup>th</sup> seconds.
20. The positions of two joggers at each second of time are shown below. They are jogging to the right.

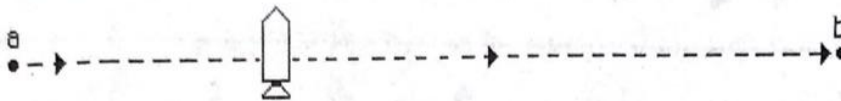


Which jogger is speeding up more quickly? That is, which jogger is accelerating more?

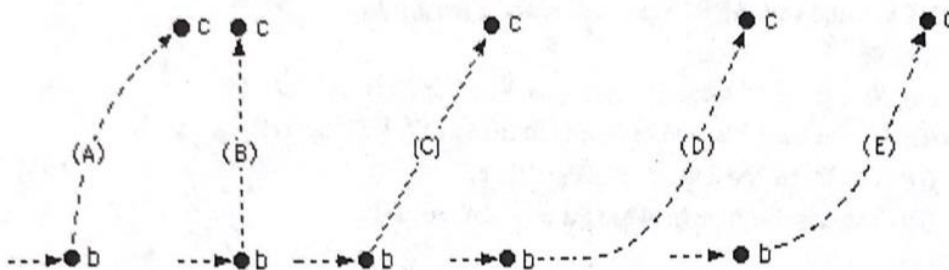
- (A) Jogger a.  
 (B) Neither. Both *are* speeding up, and in the same way.  
 (C) Jogger b.  
 (D) Neither is speeding up; their speeds *aren't* changing.  
 (E) Not enough information to answer the question.

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

Imagine that you're a space traveler far in the future; you're traveling to another star system. Your spaceship drifts sideways in outer space from location **a** to location **b**. No forces act on the ship during this time. At **b**, the captain turns on the ship's engine, producing a force (called a **thrust**) on the ship at a right angle to the line **ab** (toward the top of this page). The thrust stays constant until the ship reaches some location **c**.



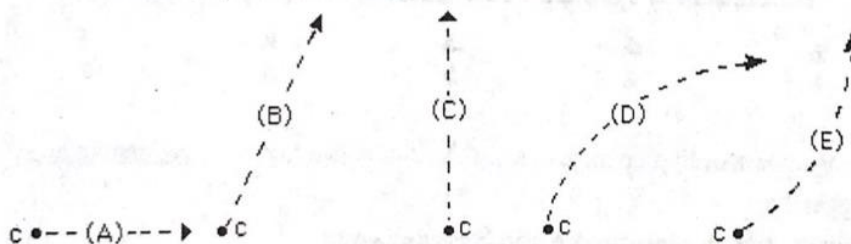
21. Which path below does the spaceship take between locations **b** and **c**?



22. As the spaceship moves from location **b** to **c**, its speed:

- (A) is constant.
- (B) is increasing.
- (C) is decreasing.
- (D) increases for a while and then stays constant.
- (E) is constant for a while and then decreases.

23. At location **c** the captain turns off the spaceship's engine, so the thrust from the engine drops to zero. Which path does the ship follow beyond location **c**?



24. Beyond location **c**, the spaceship's speed:

25. You push a large empty box slowly with a constant horizontal force, so that it moves down your school hallway at a constant speed. The force that you apply is:

- (A) the same as the weight of the box.
- (B) greater than the weight of the box.
- (C) the same as the total friction forces that resist the box's motion.
- (D) greater than the total friction forces that resist the box's motion.
- (E) the only horizontal force on the box.  
The friction forces aren't "real".



26. If you now push the box with twice the constant force of question #25, its new speed:

- (A) is constant and is twice the speed before.
- (B) is constant and is greater than the speed before, but not necessarily twice as fast.
- (C) is constant (and greater than before) for a little while; then it increases steadily.
- (D) increases for a little while, and then stays constant.
- (E) immediately starts increasing steadily.

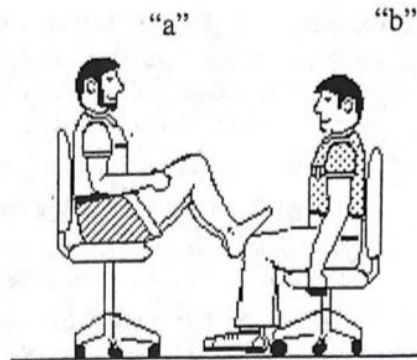
27. If you suddenly stop touching the box, it will:

- (A) stop immediately.
- (B) keep moving at the same speed for a little while, and then slow to a stop.
- (C) immediately begin slowing to a stop.
- (D) continue moving at the same speed.
- (E) speed up, and then slow to a stop.

28. Student **a** weighs 160 pounds and student **b** weighs 120 pounds. They sit in identical office chairs facing each other. The chairs have wheels.

Student **a** puts his feet on the knees of student **b** and suddenly pushes outward with his feet, causing both chairs to move.

During the push and while the students are still touching each other, which student applies a **larger** force on the other?



- (A) Neither student applies *any* force on the other; they move because they're in each other's way.
- (B) **a** applies a force on **b**, but **b** doesn't apply *any* force on **a**.
- (C) **b** applies the larger force.
- (D) **a** applies the larger force. **b** applies a smaller force.
- (E) Each student applies the same strength force on the other, but they react differently.
29. You're skuba diving, and you're resting motionless under water to enjoy the scenery for a while. What upward and downward forces act on you?

- (A) Only a downward force of gravity.
- (B) A downward force of gravity and an upward force due to the water.
- (C) Only a downward force due to the water.
- (D) A downward force of gravity and a downward force due to the water.
- (E) No forces.



30. You're playing tennis in a strong wind, and you hit a tennis ball so that it goes over the net and lands in your opponent's court. What forces act on the tennis ball while it's in the air (and not touching the racquet)?

- (A) Only a downward force of gravity.
- (B) A force of gravity and the force of the "hit".
- (C) A force of gravity and a force by the air.
- (D) The force of the "hit" and a force by the air.
- (E) All three forces: a force of gravity, the force of the "hit", and a force by the air.



APPENDIX C  
TIME ON-TASK DATA COLLECTION CHART

Class Period: \_\_\_\_\_ Date: \_\_\_\_\_

✓ = On-Task

X = Not On-Task

Student	:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30	8:00	8:30	9:00	9:30	10:00	
1																					
2																					
3																					
4																					
5																					
6																					
7																					

Student	Additional observations
1	
2	
3	
4	
5	
6	
7	

APPENDIX D  
STUDENT PERCEPTION SURVEY

## Perception of Physics 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.

Directions: Answer the following questions as honestly as you can.

\* Required

How much attention did you give yesterday's lesson? \*

	1	2	3	4	
No attention	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	A lot of attention

During yesterday's lesson, my mind wandered. \*

	1	2	3	4	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

If Mr. Rider asked you to explain exactly what you learned yesterday, I would be able to explain it. \*

	1	2	3	4	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

Yesterday's lesson sparked my interest in the physics concept we learned. \*

	1	2	3	4	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

Explain what parts of the lesson interested you or did not interest you. \*

Your answer

Yesterday's lesson motivated me to keep learning about the physics concept we learned. \*

	1	2	3	4	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

Explain what parts of the lesson motivated you to keep learning or did not motivate you. \*

Your answer

Yesterday's lesson in physics was engaging. \*

	1	2	3	4	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

Explain what parts of the lesson made it engaging or not engaging. \*

Your answer

What motivates you the most to do well in physics? \*

- Myself
- My grade
- My teacher
- My parent(s)/guardian(s)
- Competition/games in class
- Other:

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APPENDIX E  
INTERVIEW AND FOCUS GROUP PROTOCOL

**Interview/Focus Group Questions**

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

1. Think about yesterday's lesson. Did you stay focused on the lesson or did your mind wander? Why?
2. Which parts of the lesson kept your attention? Why did they keep your attention?
3. What was the point of yesterday's lesson? What skill/concept did you learn yesterday?
4. What parts of the lesson interested you the most? Would you want to keep learning more about that topic? Why?
5. Was the lesson engaging (did you have fun?). What parts made it fun?
6. What is your biggest motivator to learn physics? Explain why this motivates you.

APPENDIX F  
CLASSROOM ASSESSMENT TECHNIQUES

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

### **Minute Paper**

Take 60 seconds and write as much as you can (in complete sentences) what you learned today about physics. For example, explain the skills, concepts, ideas, equations, etc. that you learned today.

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

### **Muddiest Point**

Think about today's lesson. What was the "muddiest" point? In other words, what part of the lesson made you the most confused or didn't quite make sense? Explain why.