Testing the Efficacy of Simulations in Physics Secondary Education

A Major Qualifying Project

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

DEGREE OF BACHELOR OF SCIENCE

By:

Patrick McCarthy

May 2021

Abstract

This project intends to determine the efficacy of a simulation-based classroom structure in two ways. The first of which is to compare the new classroom structure to the existing structure, the new structure being the simulation-based classroom and the existing structure being the laboratory-based classroom. This will be done by comparing the student scores on the part of the class which will be the most changed, the Labs. This is where the comparison will be made because a majority of the two structures will be very similar except for these Labs. The second method of comparison will be a pretest and a corresponding posttest on content which has been taught to them using the simulations. This method was selected because it is a very standard way of measuring student learning in classrooms and achieving a high student learning is the goal of every classroom. The simulation-based classroom is important because it allows for a classroom in which a school may not be able to afford the expensive equipment required to do some of the experiments to be done not only by the students in the same way as in a laboratory-based classroom, but also in ways which would be very difficult even for well-funded schools.

Contents

Acknowledgements

I would like to thank my advisor Rudra P Kafle for his unending support and guidance, this project and the corresponding research would be a shadow of what it is without the assistance he provided.

I would like to thank and acknowledge the WPI Teacher Preparation Program as well as specifically Shari Weaver and Jacklyn Bonneau, for making this project possible.

I would like to acknowledge Leominster High School as well as all their faculty and staff, and specifically thank James Sheehan for allowing me to teach in his classroom.

Lastly I would like to thank my parents and the brothers of the Delta Sigma Phi Chapter of Alpha Chi Rho for their unending support throughout the Covid-19 Pandemic.

1 Introduction

This research was conducted with the assistance of Leominster High School, with data being collected while I was student teaching there. While student teaching at Leominster High School I oversaw four classes, which will be referred to as Groups A-D. The goal of this research is to compare a simulation-based classroom to a laboratory-based classroom, as well as compare it to other classrooms based on their performance on a pretest and posttest. These two methods have been selected because the laboratory-based classroom is what is seen as a traditional classroom today. The pretest and posttest however will allow the classroom to be compared to other classrooms and make sure that it is deemed effective enough to be utilized in a classroom setting. To achieve these aims I decided to compare the 92 students who I oversaw to the 119 students who had been taught by my mentor teacher the previous year. The idea was that the students who were in the simulation-based classroom which I designed would be compared in the students who were in the laboratory-based classroom which my mentor teacher had been using for an extended period. This was a secondary option since the students which I was teaching would not be able to be in person due to the Covid-19 pandemic, and as such would be doing online learning. This made it such that they could not be compared to themselves in terms of comparing laboratory-based classrooms to simulation-based classrooms, instead this was chosen as the only viable alternative given the constraints. The pretest and posttest were obtained through the force concept inventory, and as such can be verified to be both an effective test of the student learning of the content. Additionally, it is a nationally recognized test which is given in classrooms across the country, and as such can be used to compare the efficacy of the simulation-based classroom on a national scale. With the content of the pretest and posttest being taught exclusively through the simulations and the simulation-based classroom.

2 Background

2.1 Overview

To understand any body of research it is important to understand why it occurred. This research occurred for a simple reason, to determine if an alternative classroom style was effective at teaching students physics. Alternative classroom formats were made possible thanks to the Every Student Succeeds act to address diverse learning styles. However, this research was slightly hindered because it occurred during the Covid-19 pandemic.

2.2 Education Reform

Every Student Succeeds is the name for guidelines which are mandated by the government and used to regulate classrooms in public schools. As a part of the Elementary and Secondary Schools Act of 2015, the policy was reformed from the existing policy (No Child Left Behind) into its more modern iteration Every Student Succeeds (Klein, 2020). The old policy encouraged such things as large scale nationwide standardized testing, and evaluating teachers and schools based on how the students performed on those tests. Every Student Succeeds is instead focused on student wellbeing, as well as academic performance (Klein, 2020). What this means is that teachers have a lot more freedom to teach how they want and to try to develop better ways of meeting student learning goals for their classroom.

2.3 Learning Styles

Traditionally people tend to think that everyone they know learns the same way that they do, and as such if something made perfect sense to them, it would also make perfect sense to everyone else, this is in fact not entirely correct. While something can be explained with clarity, what is usually more important is how the instruction correlates to the given individual's learning styles. "Learning style is a biologically and developmentally imposed set of personal characteristics that make the same teaching method effective for some and ineffective for others" (Dunn, Beaudry, & Klavas, 2002). Some examples of learning styles are Spatial learners, Musical learners, and Kinesthetic learners, Linguistic learners, Mathematical learners, Interpersonal learners, Intrapersonal learners, and Naturalistic learners. These different learning styles are used to help describe how people learn, and why some techniques can be more effective than others for specific people.

2.4 Benefits of online learning/Simulations

An online laboratory simulation is exactly what it might sound like, a module which is on the internet which allows someone to simulate a laboratory environment or experiment, without using the necessary lab equipment. Some of the more obvious benefits come into play when you think not of large well-funded labs, but underfunded schools; or even regularly funded schools, because this allows for the students to perform labs which would otherwise be next to impossible (Wieman, Adams, Perkins, 2008). Additionally, not all the properties can be observed easily in a normal laboratory setting, for example the propagation of sound waves through air, since the air cannot be seen by the human eye under normal circumstances the simulation supplies a clean way to view sound waves (Wieman, Adams, Perkins, 2008). The last major benefit which I shall describe, though not the last one overall, is the fact that these simulations are publicly available, and as such the people who are using them to teach or to learn can use them if they have access to the internet (Wieman, Adams, Perkins, 2008). This can be extremely helpful for people who learn at a different pace than the classroom provides for them (Wieman, Adams, Perkins, 2008). The classroom must go at a certain pace to benefit the largest number of students, however if the students who need more time have access to the simulations, then they can just take that time outside of class (Wieman, Adams, Perkins, 2008). Additionally, on the other end of the spectrum, for students who is learning is faster paced than the class, they can use these simulations and similar ones which are available in the same place to further their own learning as well as to help them gain an interest in the field of physics (Wieman, Adams, Perkins, 2008).

2.5 What is a PhET (Physics Education Technology) simulation?

There are many different simulations which exist on the internet and can be used in a classroom. For this research I used simulations from the Physics Education Technology (PhET) Project (Wieman, Adams, Perkins, 2008). These simulations are especially useful for a High School classroom because they simulate the real world, and in doing so allow for computer simulated experiments or explorations to behave like experiments in physical laboratories (Wieman, Adams, Perkins, 2008). Though they are not the only options available, they were the best options for the mechanics part of the course which was being taught. There are other simulations which are better suited for such things as electricity and magnetism (Project, *Physlet® physics 3E*). The PhET simulations however are very useful for teaching mechanics (*PhET interactive simulations*).

2.6 Accounting for the Covid-19 Pandemic

It is important to recognize that this research was performed during the Covid-19 pandemic, and on account of this there are several factors which changed the way the research had to be done. The students were never at any point during the duration of the research inside of the same building as any of the researchers. In addition, all the students did their learning through online mediums. As such they were being instructed in a manner which is poorly researched. Finally, the long-term effects of living through a global pandemic are also not well understood at this time.

3 Methodology

3.1 Overview

Overall, the intention of the research was to compare the simulation-based classroom to the laboratory-based classroom, and while the pandemic complicated this, it also allowed for a unique situation in which a laboratory-based classroom would be impossible. As such no data on a laboratory-based classroom could be gathered using the students who were present in the classroom I taught in, and as such data had to be based on students from previous years which had been collected by Leominster High School. The rest of this section will focus on the simulation-based classroom in which I oversaw while gathering data. In this classroom there were two types of data being gathered. First how well the students performed on the assignments which were built around specific experiments; these were referred to as Labs. Second the improvement in the student's performance between a pre-test and a post-test which was acquired through the Force Concept Inventory.

3.2 The Classroom

It is important to say that while all the teaching occurred in the same classroom at Leominster High school, and the simulations which were implemented were all the same and from the same place, not every student came into the class with the same level of mathematical understanding. Some of the students were what the school referred to as Honors students, which meant that they were taking advanced classes like advanced Physics and advanced Math. As such the assignments which went along with the simulations had to be broken down into two versions, the normal version which was for the average student, and the honors version which was intended for the advanced students. The honors versions usually involved more calculations and a greater degree of math, as opposed to primarily conceptual ideas.

The intention was to try to do one experiment every week to every other week. However, on account of the complications due to the COVID-19 pandemic the pace was more like one experiment every third week. As such during the entire time of gathering data (sixteen weeks) a total of 5 labs were able to be completed and analyzed in this classroom with these students.

3.3 Integration of Simulations

Since a simulation-based classroom is much less common than a laboratory-based classroom the simulations had to be integrated into the classroom such as to not negatively affect the learning of the students in the classroom. To this end the first experiments where not performed using simulations, but instead laboratory like circumstances created by the students in their own homes. This was slowly transitioned to using the simulation exclusively, as it was important to make sure that the student's familiarity with the simulation was such that it would not negatively affect the research.

3.4 Pre/Post Test

This research shows effectiveness in a classroom, and as such it must depict that the primary goal of a classroom is being met. I hope that all will agree when I say that the primary goal of a classroom is student learning, or that the students grow to understand the content which is being taught to them. The comparison of the student scores on a pre-test and a post-test was selected to measure the student learning in this classroom environment. The pretest and posttest were obtained through the FCI (force concept inventory) and for that reason cannot be included in this document. The pre-test was administered at the beginning of the unit on forces and Newton's Laws, which occurred at a point in the year such that some of the concepts on the pre-test had already been covered, but not in this unit. They were however still covered in a unit which used simulations to display the content. The unit used several different simulations, primarily through the PhET platform.

The post-test was administered at the end of the unit and was identical to the pre-test. To help avoid students simply studying the pre-test, the grades for the pre-test were not given back until after the post-test had concluded. The format of the test was a thirty (30) question multiple choice test, which as the name Force Concept Inventory (FCI) suggests was on force concepts. This meant no math was involved, instead it was all conceptual. This was intended to allow the honors students and the regular level students to have an equal ability to do well on both tests.

3.5 Comparing the Data

There are two separate methods by which the data will be analyzed depending on what type of data it is. The actual grades of the students from this year and those of the students from last year will be compared by means of simple statistical comparisons such as comparison of the average or mean value of the student performance on each experiment, as well as the spread, or standard deviation of the values. In addition, if necessary, the shape of the data will be analyzed, however if both form standard normal distributions then this will be ignored. For the pretest and post test data the learning gain will be calculated. The following is the equation for learning gain.

$$\frac{p_2 - p_1}{100\% - p_1}$$

$$p_1 = \text{Score on the pre-test}$$
$$p_2 = \text{Score on the post-test}$$

The learning gain is the standard method to determine how much students improved between a pretest and a posttest (Freeman et al., 2014). It is calculated by dividing the actual increase between the two tests by the possible increase between the two tests. It is useful because it both benefits students who did not have a lot of room to improve for improving but also the students who had a large amount to improve achieving some improvement (Freeman et al., 2014). As such it is crucial in the determination of efficacy.

3.6 Justification of Comparison

The exact numerical grades allow all students to be compared as numerical data points, this not only is the best way to avoid biases but also is the way in which is most certain that the school would be willing to give the data. This is because there are no complications which can arise from this type of data collection regardless of how it is shared, since nothing connecting to the individual student is shared. On top of this fact the numerical data is required to do any statistical analysis, which is how the comparison is being done. Additionally, the learning gain is a commonly utilized method of comparing student performance on pre/post assessments of any kind.

4 Data

4.1 Lab 1

As can be seen in the graphs below the students in the simulation-based classroom did less well than the students in the laboratory-based classroom on Lab 1. This can most easily be depicted through the mean score of the students in each class, with the students in the simulation-based classroom averaging a score of 54.1% compared to the laboratory-based classroom where the students achieved an average score of 63.7%. This difference is made slightly less prominent on account of the number of students who scored a zero, by not submitting the assignment, which was greater in the laboratory-based classroom by 7 students. This difference is slightly misleading though since the laboratory-based classroom had 27 more students than the simulation-based classroom, which could be one explanation for the difference in mean.

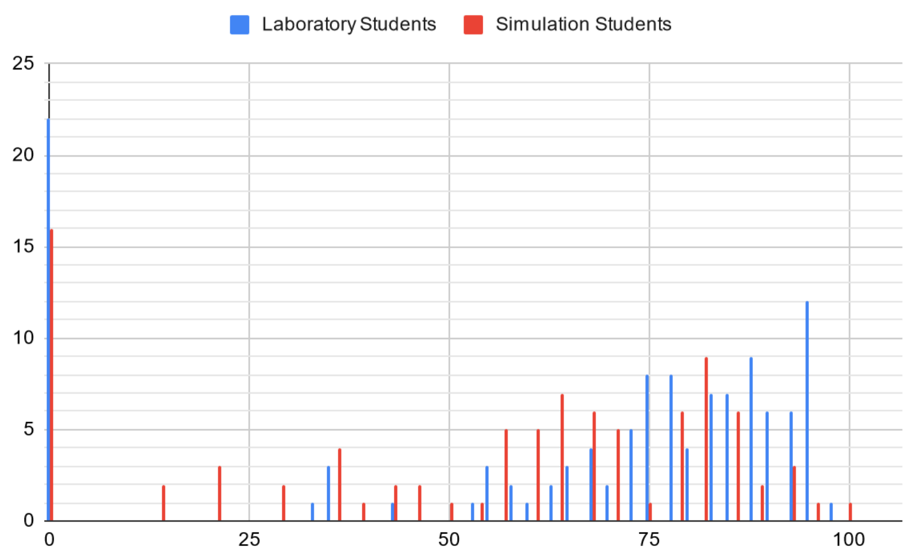

Figure 1: The student scores on Lab 1 compared to the number of students who achieved those scores for both the Laboratory-based classroom as well as the Simulation-based classroom.

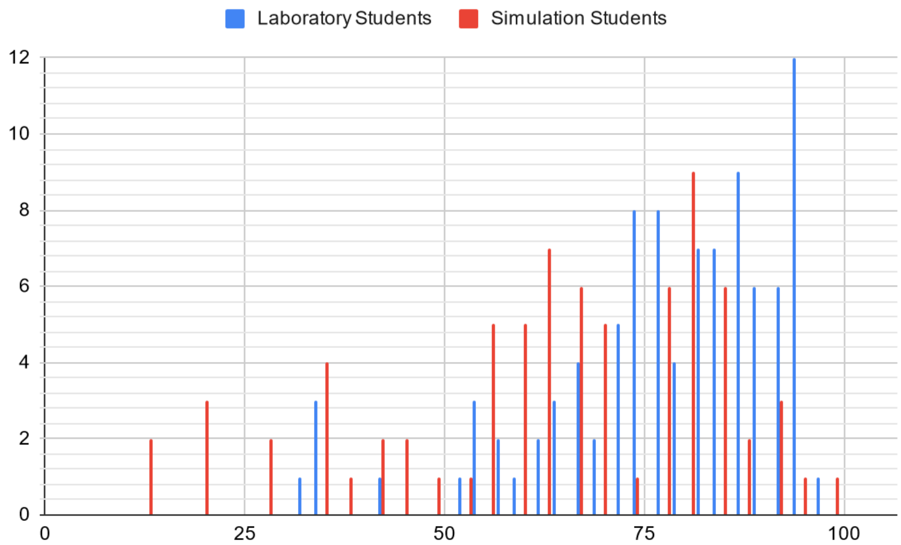

Figure 2: The student scores on Lab 1 compared to the number of students who achieved those scores for both the Laboratory-based classroom as well as the Simulation-based classroom. Figure 2 however removed all the students who scored a zero such that the rest of the data can be seen more clearly.

4.2 Lab 2

As can be seen in the graphs below the students in the simulation-based classroom once again did less well than the students in the laboratory-based classroom on Lab 2. The difference on Lab 2 is even more pronounced than in Lab 1, with many of the students in the simulation-based classroom scoring even worse than the worst score on Lab 2 in the laboratory-based classroom, not counting the students who did not submit the assignment. The distributions for the scores speak volumes even without the scoring means because there is clearly a much greater cluster of students in the laboratory-based classroom who scored a 75% or above, whereas the simulation-based classroom shows almost no grouping whatsoever. This is easily shown as well through the two mean scores, with the simulation-based classroom averaging a 50.9% and the laboratory-based classroom averaging a 67.9%.

The mean being higher, and the existence of a grouping are strong signs which lead to the notion that the simulation-based classroom is worse, it is important to recognize that both more students did not submit the assignment in the simulation-based classroom.

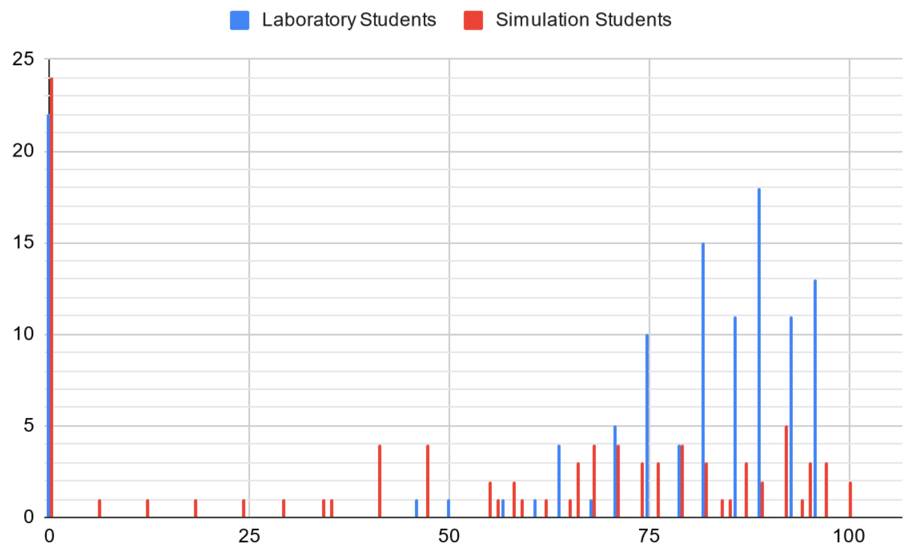

Figure 3: The student scores on Lab 2 compared to the number of students who achieved those scores for both the Laboratory-based classroom as well as the Simulation-based classroom.

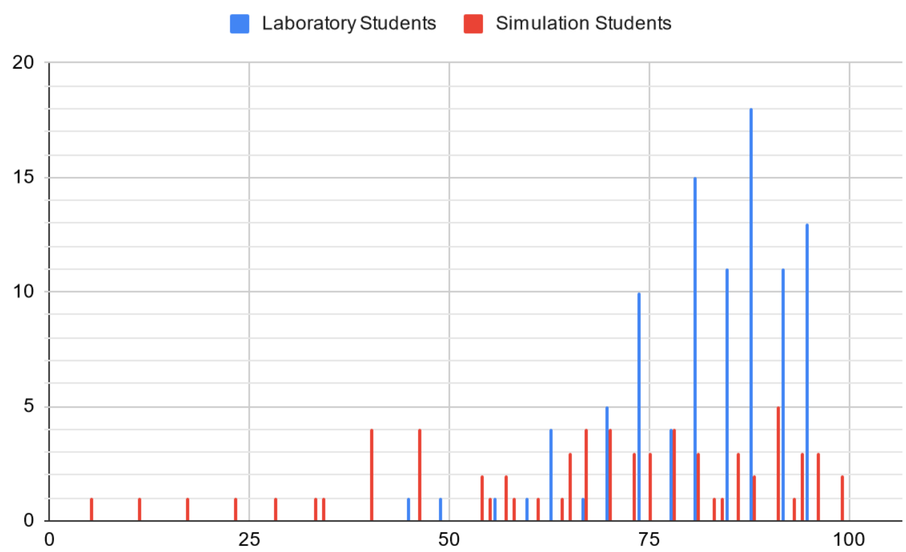

Figure 4: The student scores on Lab 2 compared to the number of students who achieved those scores for both the Laboratory-based classroom as well as the Simulation-based classroom. Figure 4 however removed all the students who scored a zero such that the rest of the data can be seen more clearly.

4.3 Lab 3

Lab 3 is in an interesting place when compared to the other two, as this assignment was only given to the honors students in the simulation-based classroom, which only includes 46 students. As such all comparisons should be made cautiously because this lab compares what is believed to be the best students from the simulation-based classroom to all students in the laboratory-based classroom. In addition, it is important to note that the laboratory-based classroom contained students who scored above the traditional maximum score of 100%. With these factors in mind, we should note that the laboratory-based classroom still on average performed better than the simulation-based classroom. With the average from the simulation-based classroom being a 59.9% and the average from the laboratory-based classroom being a 75.5%.

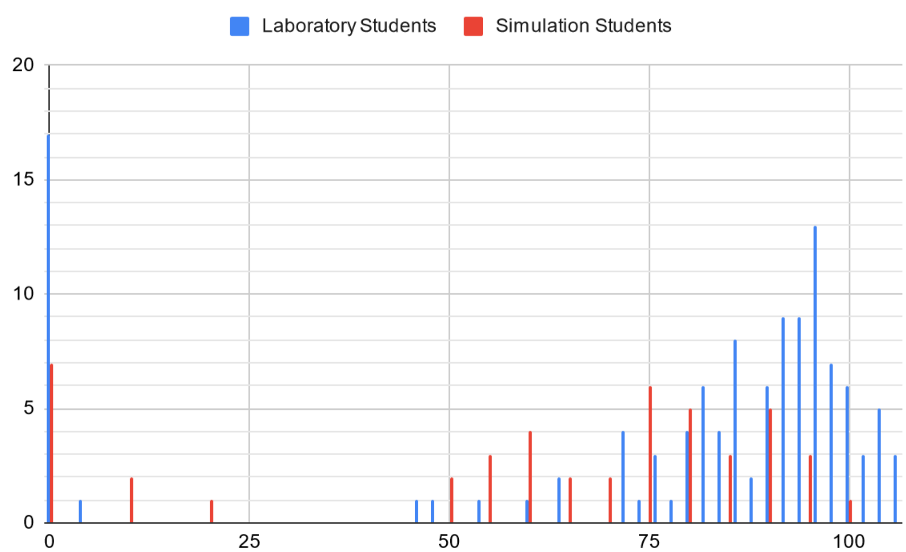

Figure 5: The student scores on Lab 3 compared to the number of students who achieved those scores for both the Laboratory-based classroom as well as the Simulation-based classroom.

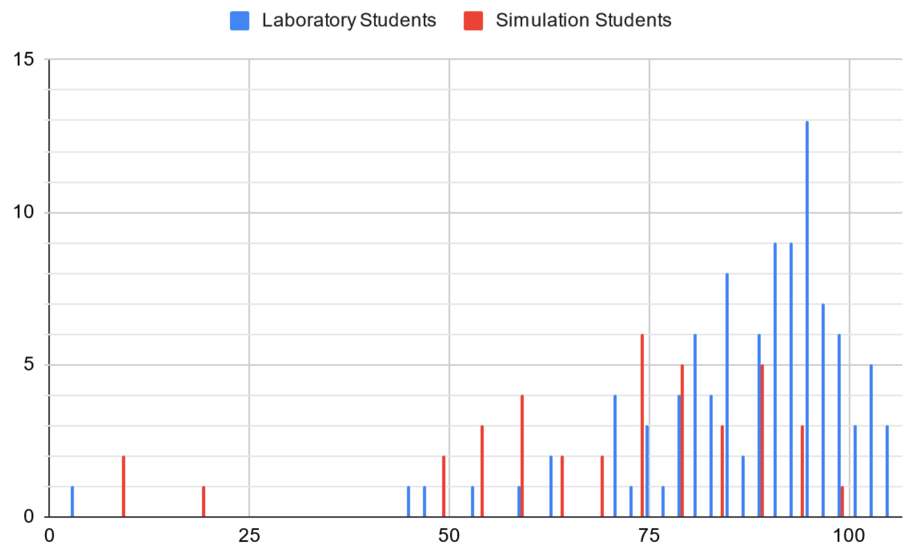

Figure 6: The student scores on Lab 3 compared to the number of students who achieved those scores for both the Laboratory-based classroom as well as the Simulation-based classroom. Figure 6 however removed all the students who scored a zero such that the rest of the data can be seen more clearly.

4.4 Pre/Post Test

The pretest and posttest tell a very different story than comparing the labs did. The pretest and posttest were acquired through the FCI (Force Concept Inventory) and as such were on the topic of forces. The scoring distribution for both the pretest and the posttest can be seen below. Through these distributions the fact that students benefitted from the simulation-based classroom is made apparent. The number of students in the pretest who scored above a 20 out of 30 is 2, whereas that number increases to 23 in the post test. Additionally, the average score increased from 27.2% to 48.5% which a near doubling of average score.

Additionally, below is each student's individual improvement with the black bar being a given student's pretest score and the red bar being that same given student's posttest score, with the difference being depicted in pink. These are important to include because they are necessary in both visualizing individual student performance, but also necessary to verify the learning gain calculations.

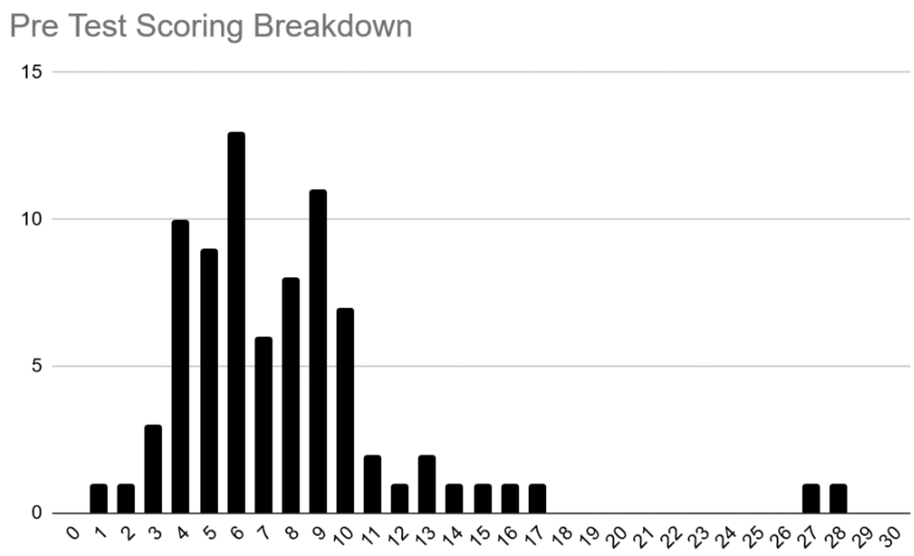

Figure 7: The student scores on the pre-test from the simulation-based classroom, with the scores out of thirty on the x-axis and the number of students who achieved that score on the y-axis.

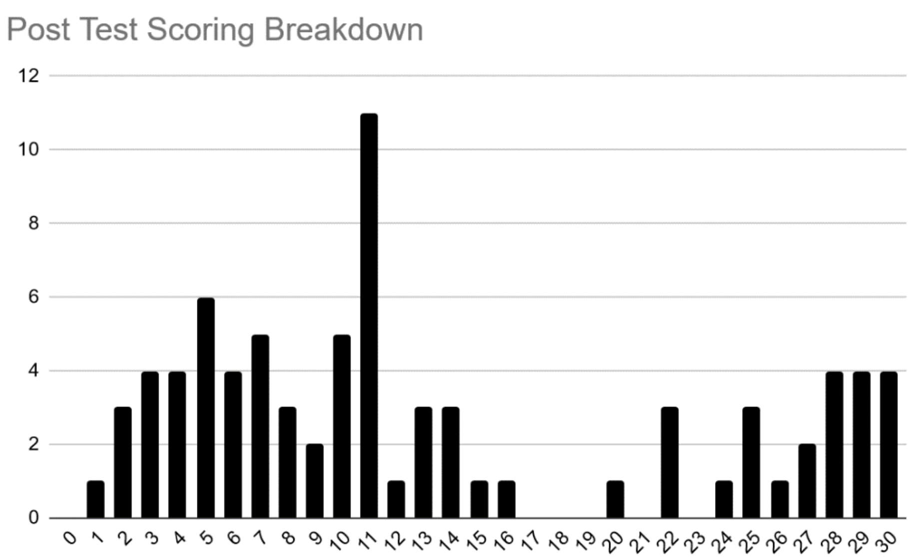

Figure 8: The student scores on the post-test from the simulation-based classroom, with the scores out of thirty on the x-axis and the number of students who achieved that score on the y-axis.

4.4a Group A

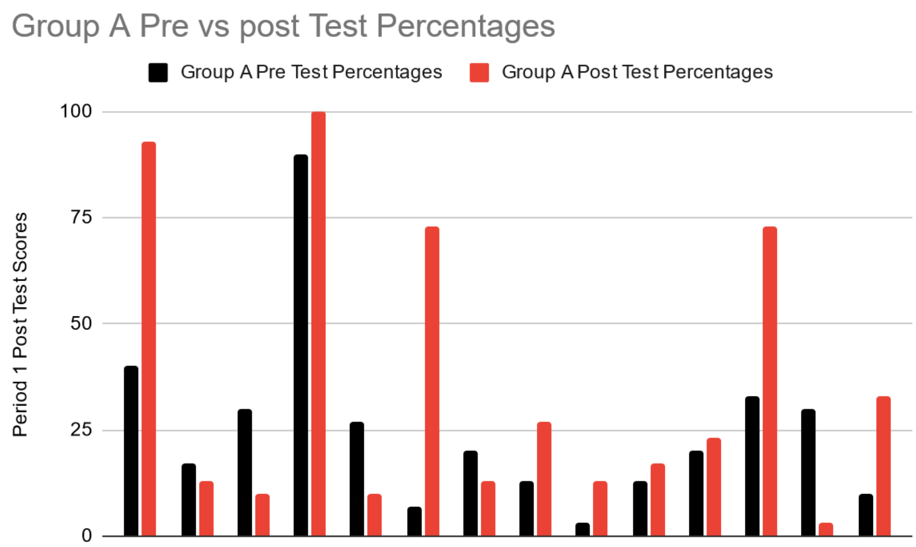

Figure 9: The Group A student scores on both the pre-test and post-test compared side by side, with the pre-test scores in black and the post-test scores in red.

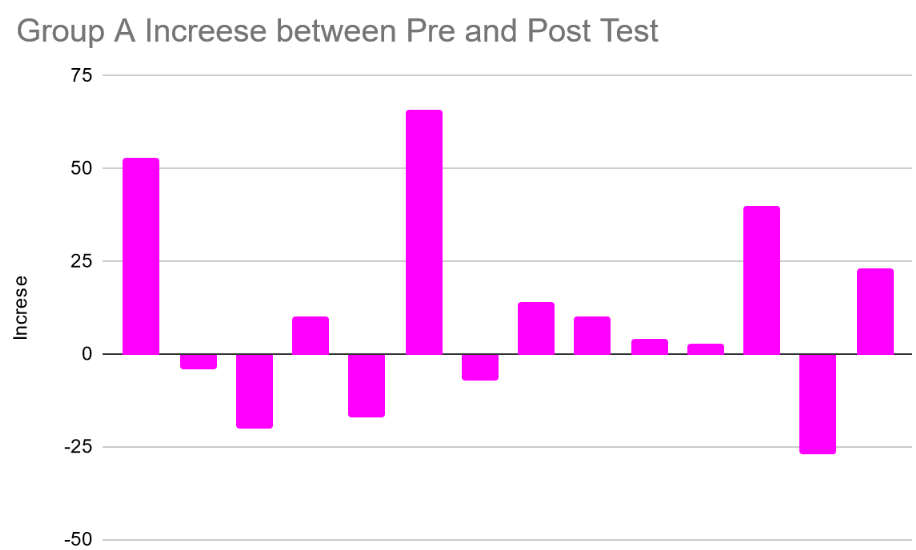

Figure 10: The numerical difference between the pre-test scores and the post-test scores for students in Group A

4.4b Group B

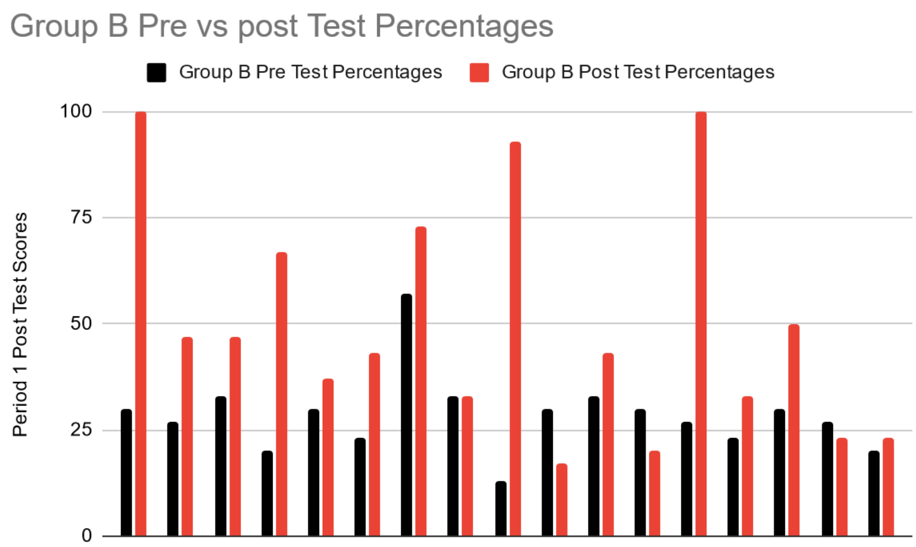

Figure 11: The Group B student scores on both the pre-test and post-test compared side by side, with the pre-test scores in black and the post-test scores in red.

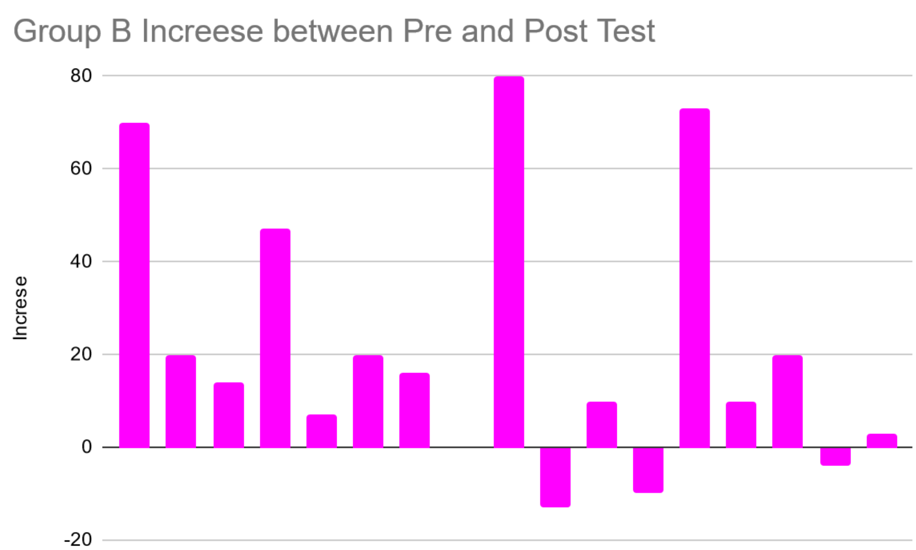

Figure 12: The numerical difference between the pre-test scores and the post-test scores for students in Group B

4.4c Group C

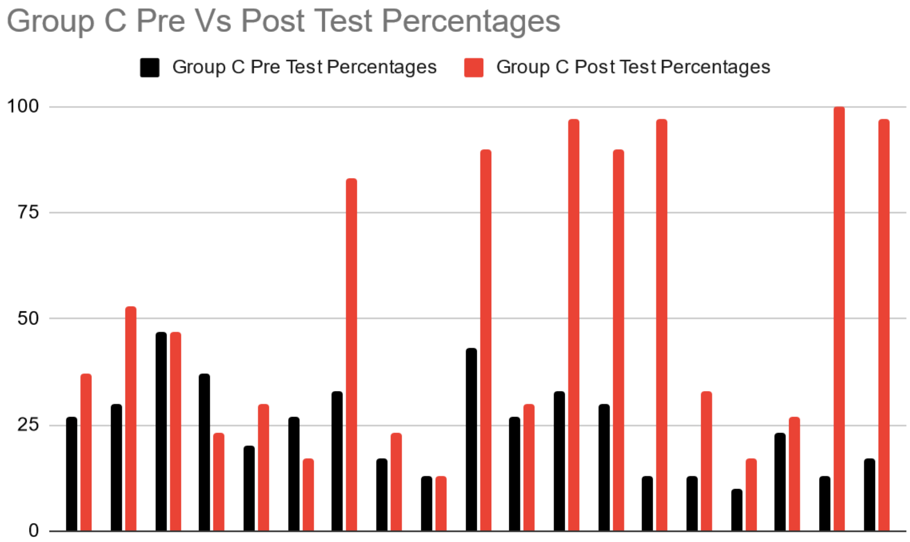

Figure 13: The Group C student scores on both the pre-test and post-test compared side by side, with the pre-test scores in black and the post-test scores in red.

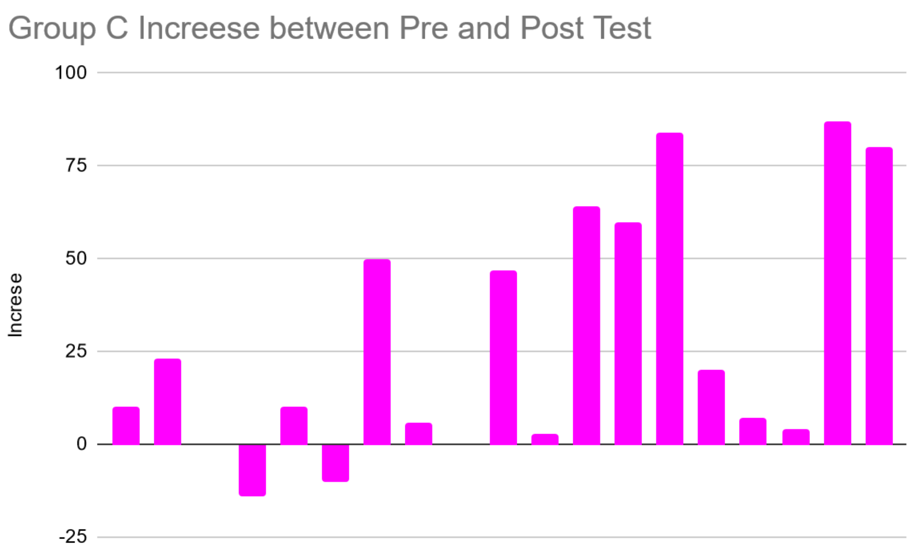

Figure 14: The numerical difference between the pre-test scores and the post-test scores for students in Group C

4.4d Group D

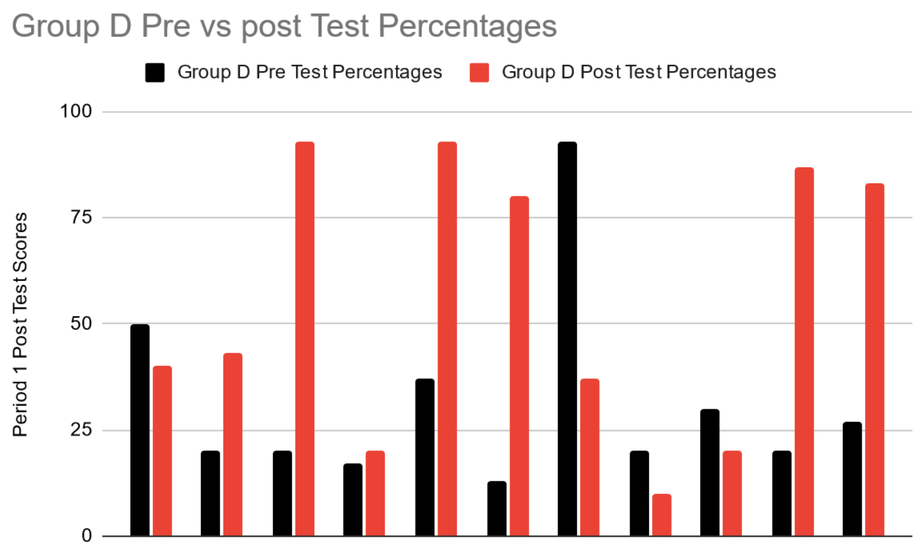

Figure 15: The Group D student scores on both the pre-test and post-test compared side by side, with the pre-test scores in black and the post-test scores in red.

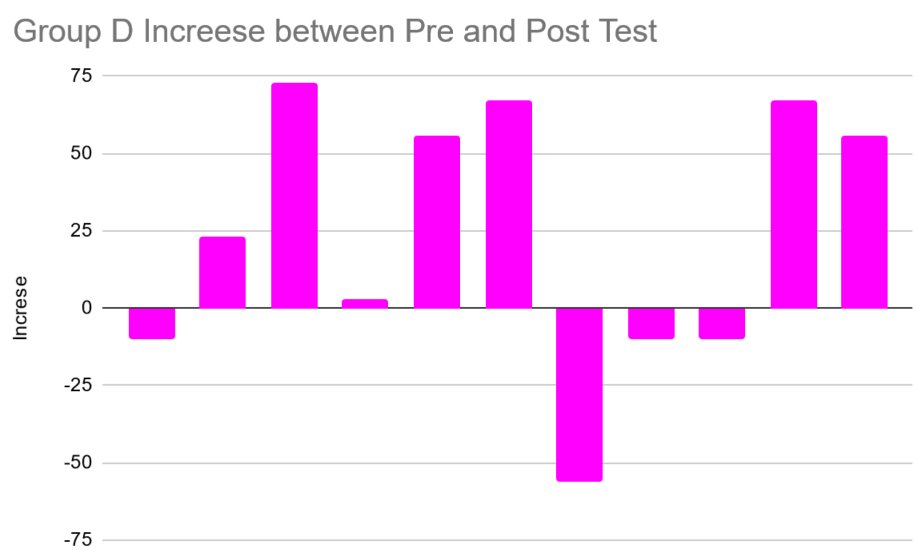

Figure 16: The numerical difference between the pre-test scores and the post-test scores for students in Group D

5 Conclusion

The research appears to show two contradictory results when it comes to the thing which was being tested, the efficacy of a simulation-based classroom. First there is the data which compares the student's performance on Labs in both the simulation-based classroom and the laboratory–based classroom, in which the data appears to say that a simulation-based classroom is less effective than a laboratory-based classroom. However, if we look at the learning gain between the pre and the post test,

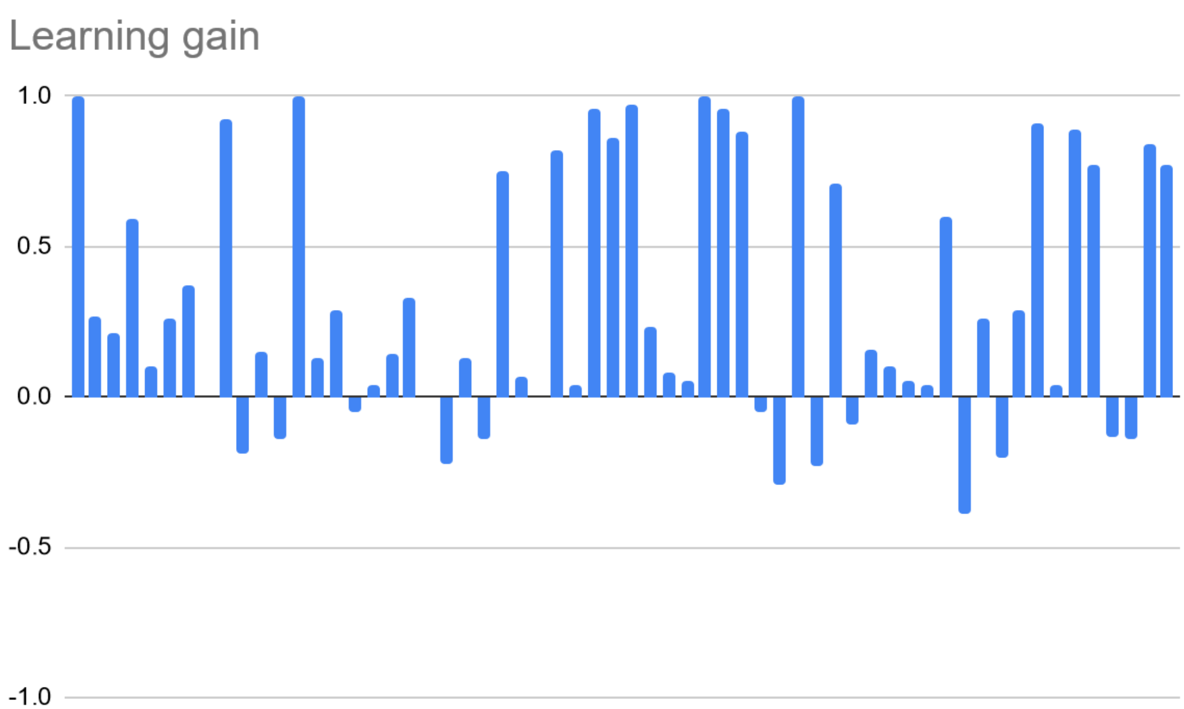

Figure 17: The value for the learning gain for each student in the entire class with 1.0 being the maximum achievable value and major outliers removed. Each bar is an individual student.

we can see that a fair number of students had a strongly positive learning gain, with the average learning gain being 0.313 this falls into an acceptable range of 0.25 to 0.5. To reconcile the conclusions, we must consider what may be impacting our results. First it is distinctly possible that the simulation-based classroom is less effective than the laboratory-based classroom, but still effective enough to be deemed a suitable classroom structure. Alternatively, there is a possibility that the data was confounded at least partially by the Covid-19 pandemic, since the students in the laboratory-based classroom were not dealing with a pandemic and the students in the simulation-based classroom were dealing with the pandemic. As an individual who was both a student and a teacher during this pandemic, I feel confident that at the very least the data should be replicated in a situation in which either neither classroom or both classrooms are in a pandemic. This way we can be certain that the pandemic did not confound any results. However, it is still important to recognize that even during the pandemic the simulation-based classroom achieved a learning gain which fell between acceptable bounds.

As such I conclude that the preliminary data, which should be replicated, says that a simulation-based classroom is an effective way of teaching students, however not necessarily better than a laboratory-based classroom.

6 References

Dunn, R., Beaudry, J. S., & Klavas, A. (2002). *Survey of Research on Learning Styles* [PDF]. Sacramento, CA: California Journal of Science Education.

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations That Enhance Learning. *SCIENCE EDUCATION FORUM, 322*, 682-683. doi:10.1126/science.1161948

Klein, A. (Ed.). (2020, December 09). The every student succeeds act: An essa overview. Retrieved April 16, 2021, from https://www.edweek.org/policy-politics/the-every-student-succeeds-act-an-essa-overview/2016/03

Project, P. (n.d.). Physlet® physics 3E. Retrieved May 06, 2021, from https://www.compadre.org/physlets/

U. (n.d.). PhET interactive simulations. Retrieved May 06, 2021, from https://phet.colorado.edu/

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderot, M. P. (n.d.). Active learning increases student performance in science, engineering, and mathematics (1360557786 995545822 B. Alberts, Ed.). doi:https://doi.org/10.1073/PNAS.1319030111

7 Appendix

Lesson Plans:

Lab 1

Lesson Plan Title: Acceleration lab

Teacher's Name: Patrick McCarthy **Subject/Course: Physics**

Unit: 1D Kinematics **Grade Level: 11**

Overview of and Motivation for Lesson:

Students will spend the entirety of the class period gathering data for a lab by rolling a given round object down a ramp from a given height and then measuring how long it takes to travel a given distance, close to 50 centimeters, then will repeat this at least 2 more time. Then will use this data to answer a number of questions including the acceleration of the round object. This will allow for the students to both learn to take data as well as understand that even the most well-made experiments are not perfect.

Stage 1-Desired Results
Standard(s): • HS-PS2-1. Analyze data to support the claim that Newton's second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force. Clarification Statements: • Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, and a moving object being pulled by a constant force.
Aim/Essential Question: • What is acceleration and how does it affect the world around us
Understanding(s):

Students will understand that . . .

- Objects which are moving down a ramp accelerate at a constant rate
- Objects rolling along a level surface do not accelerate
- Taking multiple trials of a lab will improve accuracy but not precision

Content Objectives:

Students will be able to . . .

- Perform an experiment
- Write scientifically about it
- Analyze sources of error

Language Objectives:

ELD Level Choose an item. *Students will be able to . . . in English*

- Click here to enter text.

ELD Level Choose an item. *Students will be able to . . . in English*

- Click here to enter text.

Key Vocabulary

- Acceleration
- Velocity
- Displacement
- Time
- Accuracy
- Precision
- Sources of error
- Random error
- Systematic error

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- The students will complete a lab as well as an associated worksheet which will require the students to think about their work scientifically.
- The lab will consist of the students rolling a ball down a ramp of some kind and then marking how long it takes to travel a certain distance.

Key Criteria to measure Performance Task or Key Evidence

- The ability to answer the questions which are being asked on the lab correctly
- The ability to record and analyze data
- The amount of error and how much was systematic and how much was random

Stage 3- Learning Plan

Learning Activities:

Do Now/Bell Ringer/Opener: Click here to enter text.

Learning Activity 1:

Students will spend the entirety of the class period gathering data for a lab by rolling a given round object down a ramp from a given height and then measuring how long it takes to travel a given distance, close to 50 centimeters, then will repeat this at least 2 more time. Then will use this data to answer a number of questions including the acceleration of the round object.

Learning Activity 2:

Click here to enter text.

Application

Click here to enter text.

Summary/Closing

Click here to enter text.

Multiple Intelligences Addressed:

☐ Linguistic	☐ Logical-Mathematical	☐ Musical	☐Bodily-kinesthetic
☐ Spatial	☐ Interpersonal	☐Intrapersonal	☐Naturalistic

Student Grouping ☐ Whole Class ☐ Small Group☐ Pairs ☒ Individual **Instructional Delivery Methods** ☐ Teacher Modeling/Demonstration☐ Lecture☒ Discussion ☐ Cooperative Learning ☐ Centers☒ Problem Solving ☒ Independent Projects	
Accommodations Click here to enter text.	**Modifications** Click here to enter text.
Homework/Extension Activities: Click here to enter text.	
Materials and Equipment Needed: • Measuring apparatus • round objects • stopwatches, or other timing apparatus	

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Lab 2

Lesson Plan Title: Free fall Lab

Teacher's Name: Patrick McCarthy **Subject/Course: Physics**

Unit: 1D kinematics **Grade Level: 11**

Overview of and Motivation for Lesson:

Click here to enter text.

Stage 1-Desired Results

Standard(s):

- HS-PS2-1. Analyze data to support the claim that Newton's second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force.

Clarification Statements:

- Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, and a moving object being pulled by a constant force.

Aim/Essential Question:

- What affects how an object falls

Understanding(s):

Students will understand that . . .

- Students will understand that free fall is simply an object moving at a constant acceleration and having an initial velocity of zero
- Students will understand all objects regardless of mass fall at the same rate in a vacuum
- That air resistance affects how fast objects fall

Content Objectives:

Students will be able to . . .

- Identify when an object is in free fall
- Identify what being in free fall guarantees about an objects motion
- Write out, but not solve equations describing the motion of an object in free fall

Language Objectives:

ELD Level Choose an item. *Students will be able to . . . in English*

- Click here to enter text.

ELD Level Choose an item. *Students will be able to . . . in English*

- Click here to enter text.

Key Vocabulary

- Acceleration
- Velocity
- Displacement
- Time
- From Rest
- Free fall
- Initial Velocity
- Final Velocity
- Free fall equations

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Students will perform an experiment in which they have to drop multiple different objects from different heights multiple times. ie, 3 objects from 3 heights, 3 times for each set of object and height.
- The students will then measure the time it takes for the objects to fall to the ground from the differing heights and then will use this data to calculate such things as the theoretical amount of time it should have taken and the experimental acceleration due to gravity
- The objects will be required to be able to be dropped multiple times and from a potentially high height

Key Criteria to measure Performance Task or Key Evidence

- The students will be assessed on their ability to calculate the actual values in the experiment
- The students will also be assessed on their ability to write scientifically
- Additionally the students will be assessed on their ability to understand the differing sources of error in the experiment and why certain things are random error and why some things are systematic error and what makes them different and how we can account for them and change the experiment such as to not have any of either.

Stage 3- Learning Plan

Learning Activities:

Do Now/Bell Ringer/Opener: Students will be asked to get three objects from around their house that they can drop safely and repeatedly from heights varying from 10 centimeters to 2 meters and to then return to the class

Learning Activity 1:

Students will then be expected to measure three different heights and mark them in some way, preferably not causing lasting damage to their homes. Then they will be asked to complete a lab in which they have to measure the time it takes for the objects to fall from a variety of heights, making sure to perform multiple trials.

Learning Activity 2:

Click here to enter text.

Application

Click here to enter text.

Summary/Closing

Click here to enter text.

Multiple Intelligences Addressed:

☐ Linguistic	☒ Logical-Mathematical	☐ Musical	☒Bodily-kinesthetic
☒ Spatial	☐ Interpersonal	☐Intrapersonal	☐Naturalistic

Student Grouping

☒ Whole Class ☐ Small Group☐ Pairs ☒ Individual

Instructional Delivery Methods

☐ Teacher Modeling/Demonstration☐ Lecture☒ Discussion

☐ Cooperative Learning ☐ Centers☒ Problem Solving

☒ Independent Projects

Accommodations Click here to enter text.	**Modifications** Click here to enter text.
Homework/Extension Activities: Click here to enter text.	
Materials and Equipment Needed: • Ruler, or meter stick • Variety of objects	

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Lab 3

Lesson Plan Title: Horizontal projectile motion LAB

Teacher's Name: Patrick McCarthy **Subject/Course: Physics**

Unit: Horizontal projectile motion **Grade Level: 11**

Overview of and Motivation for Lesson:

Students will be spending the whole day working on the lab, in which they have to roll a marble down a ramp and then have it roll off of a table, and using differing measuring apparatuses calculate the horizontal displacement.

Stage 1-Desired Results
Standard(s): • HS-PS2-1. Analyze data to support the claim that Newton's second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force. Clarification Statements:

- Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, and a moving object being pulled by a constant force.

Aim/Essential Question:

- What kinds of motion make up horizontal projectile motion

Understanding(s):

Students will understand that . . .

- horizontal projectile motion is made up of constant velocity motion in the x direction
- And free fall motion in the y direction

Content Objectives:

Students will be able to . . .

- Break down a horizontal projectile motion problem into its two parts, and solve them
- Gather data to complete horizontal projectile motion calculations

Language Objectives:

ELD Level Choose an item. *Students will be able to . . . in English*

- Click here to enter text.

ELD Level Choose an item. *Students will be able to . . . in English*

- Click here to enter text.

Key Vocabulary

- Horizontal projectile motion
- Free fall
- Starts from rest
- Position
- Velocity
- Acceleration
- Displacement
- Time

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Students will complete a lab in which they have to roll a marble down a ramp and then have it roll off of a table, and using differing measuring apparatuses calculate the horizontal displacement, and also measure it.

Key Criteria to measure Performance Task or Key Evidence

- How closely the students follow the experimental procedure
- The accuracy of the lab data
- The precision of the lab data
- The amount of detail put into the conclusion questions.

Stage 3- Learning Plan

Learning Activities:

Do Now/Bell Ringer/Opener: Click here to enter text.

Learning Activity 1:

Students will be spending the whole day working on the lab, in which they have to roll a marble down a ramp and then have it roll off of a table, and using differing measuring apparatuses calculate the horizontal displacement.

Learning Activity 2:

Click here to enter text.

Application

Click here to enter text.

Summary/Closing

Click here to enter text.

Multiple Intelligences Addressed:

☐ Linguistic	☐ Logical-Mathematical	☐ Musical	☐Bodily-kinesthetic
☐ Spatial	☐ Interpersonal	☐Intrapersonal	☐Naturalistic

Student Grouping

☐ Whole Class ☐ Small Group☐ Pairs ☐ Individual

Instructional Delivery Methods

☐ Teacher Modeling/Demonstration☐ Lecture☐ Discussion

☐ Cooperative Learning ☐ Centers☐ Problem Solving

☐ Independent Projects

Accommodations	**Modifications**
Click here to enter text.	Click here to enter text.

Homework/Extension Activities:

Click here to enter text.

Materials and Equipment Needed:

- Click here to enter text.

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*