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DOES THE MATHEMATICS LEVEL AFFECT STUDENT SUCCESS IN HIGH

SCHOOL PHYSICS?

by

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A capstone submitted in partial fulfillment of the requirements for the degree of Masters of Arts in Teaching

Hamline University

Saint Paul, MN

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DEDICATION

To my rock, my loving husband Will. To my son, Braden, without whom this would have been finished a year ago. I love you both. To my in-laws and friends for your continuous encouragement and support. To my coworkers for your inspiration to do this project. Thank you to my Capstone Committee. Your guidance and patience helped me to complete this project. I have learned a great deal from you.

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Introduction

Background

From a young age, we are trained to think that science class is just a science class, and math class is just math class. We do not think that they affect one another as much as they do. As students go through school they have their math class and their science class kept separate, just like their History and English classes are. It isn't until high school that many students start using more of their math skills outside of math class. That is when students start using math in science courses. Outside of math and science teachers and professionals, many people think that they are still two separate fields. Even though math teachers emphasize the importance of math skills to be used outside the math classroom, it is not until high school science courses that many students see that importance.

In this chapter, I will introduce you to my journey investigating my research question, "Is a Math Requirement Needed for Students Taking High School Physics?" I will write about how, as a certified teacher from a Midwestern state who moved to Southwestern state, I discovered that there are drastic differences between standards in each state. I will write about how those different standards affect my teaching and in state standards and rankings.

Journey

After I moved from the Midwest to the Southwest, there were many things that I noticed were different in the world of teaching. One difference was how the school day was run. Instead of the extracurricular activities being outside of school activity, they are included in the school schedule so the kids have a period of their school day for their sport, which takes away possible classes they could otherwise be taking. For example, some sporting events happen during school hours, making students miss class to go to an event instead of attending it after school. This ends up affecting teaching depending on how many students might be missing from a class that day, as it might end with not being able to teach or do any type of lesson that day. It also ends up affecting students learning as if they miss the same period frequently, they end up missing valuable teaching points and may be lost when they come back into class.

Another major problem I noticed was the certification process. When it comes to the certification process, in my home state in the Midwest, high school science teachers are focused on one subject--Life Science, Chemistry, Physics, or Earth Science--and have a license to teach just that subject. They are able to hold more than one science license--for example, a teacher could have both a Chemistry and a Physics license--but they must have completed the requirements for each license. It is not legal for a licensed Chemistry teacher to teach Physics, for example. In my new state in the Southwest, high school science teachers can take one test that contains all of the science subjects and then be licensed to teach all science content areas. Some of these teachers could have never taken a physics class in college or even in their life, but they could still be considered qualified to teach Physics if they have the composite science certification, which is one of many types of licenses teachers can have. Many school districts prefer teachers having the composite science certification as it allows teachers to be able to have more flexibility on which type of science they end up teaching.

The one difference that really stuck out to me as problematic was my student's math ability in my physics course. In my years of teaching Physics, I have always asked what math class students have taken, and what grade they received. This gives me an idea of how high their mathematical abilities are when taking the previous class, and of course if they were properly registered for the class. As I looked through that data for my students in my first year of teaching in the new state, I saw that many students came into my physics and chemistry classes without having Algebra 2 for Physics and without having Geometry for Chemistry. When I went to talk to a counselor about this issue, I was told that there was no prerequisite to register for this class.

As I went through my semester teaching, I received many questions from my students about the math we were using: "Why do we have equations?", "Why is there math? I thought this was science class?", "Why can't you just write the equation that way?", "Why do we have to derive equations?", "Can't I just memorize that equation instead of showing all my work?", and "Why do I have to show my work?". I also heard a statement that I'm sure is never going to change and constantly hear from my students and parents was: "I didn't know we had to do math!" Which is frustrating because it's not the first time kids have used mathematics in science, and they are acting like it is a new thing, and as if they would have never taken the course if they had known it had mathematics in it.

In fact on Day One, I like to tell the students “Physics is using math to help explain how the world works.” That was what got me interested in majoring in Physics instead of math, after all, the ability to do something with math. I fell in love with using math in actual situations that I can relate to in the world around me. That’s when I realized that the students didn't share the connection between math and science, especially in physics, before they registered for the class. Although I tell them this on those first days, it seems as if they forget two days later as we start working on our first math problems that we encounter in class. This is natural, as it is how our brain works as well as theirs, but at times seems to drive me crazy as they believe that class contents aren’t allowed to overlap.

There are many different physics courses that students are able to take at my school. They are able to take Regular Physics, PreAP Physics, and AP Physics. Each of the levels of physics requires different levels of mathematical skills. All of these courses are offered on an accelerated block to students, where the majority of the students taking it are juniors. Teaching PreAP and AP Physics, I want to be able to spend more time teaching concepts and different ways we use those concepts in our world. Because AP Physics standards include some concepts from Chemistry, Algebra 2, and Trigonometry, I include those in my curriculum. This means I end up putting more mathematics within the curriculum for PreAP Physics, and AP Physics than I would for teaching a Regular Physics course.

Instead of teaching more physics concepts as I planned to, I spent more time teaching mathematical concepts that students have learned in previous courses. Because many of my students still struggle with their mathematical skills and the process of answering a word problem, they focused more of their time on trying to do the calculations for a particular problem than really understanding the concepts and physics behind why they are doing what they are doing. When looking at student work, I see that they spend more time memorizing steps for how to do one problem, and remember that, instead of understanding what the question is asking, and how the concepts are related and applied to the question.

Many physics questions are very similar to math word problems. The only difference is that in physics, there are specific equations for students to use for certain situations. The students are able to see how these equations work through hands-on experimentation. As long as the students understand the physics concepts, and what the question is asking, they should be able to apply the concepts to the problem and solve using the right equation. My current students, however, have a hard time determining which equation to use with each problem as they have a hard time remembering the variables as they want the only variables they deal with to be x, y, and z, instead of any letter in the alphabet. They also just want to plug in numbers instead of solving problems with only variables.

I started questioning my teaching; why were so many of my students asking math skill questions more than content and concept questions? It didn't make any sense to me. When I was teaching in the Midwest at an inner-city school with 38% of the school population white, and 50% eligible for free or reduced lunch, I had students struggle on the math a little bit, but most of the time they understood what I was doing on the board and how I got the answers. The only times they had trouble was when they had done a math error or if I had gone too fast for them when working out the problem. The students I taught in the Midwest were also in a lower level Physics course than what I was teaching now. So why was it that my students in the Southwest were struggling when they were in the same grade level as the students in the Midwestern state? This coming Southwest school where 5% of students are on free and reduced lunch and the student population is 72% white students. Some of the students have taken Chemistry and Algebra 2 before taking this one, even though it is not required, and cover the same topics in standards although the Midwestern state's standards go more in-depth than the Southwestern state's standards. Yet the Midwest state's standards for their regular physics course matched the standards for the advanced physics course in the Southwest state's standards. So, why is there such a difference?

After doing some research and talking with other teachers and counselors, I found out that there is no mathematical requirement for students to take high school science courses no matter the course, where the school in the Midwestern state there is. This is decided upon by the school district itself. After doing research, it was found that many school districts still keep this in place, yet the Southwestern state district I am currently in, felt the need to get rid of all prerequisites. For a student to sign up for a high school physics course at my previous school in the Midwestern state, they first must be junior or senior to take the course and have taken Chemistry and passed. The reason for this is my junior year, most students took Algebra 2 and Chemistry as sophomores. This way they go into their junior year with all prior knowledge to help out. If they haven't taken Chemistry and Algebra 2 as sophomores, they are taking it as juniors. This then allows for more success in the class to happen as the students have the previous knowledge to help them succeed.

If the student decided to take a more advanced physics course, they have extra requirements than just having taken Chemistry. The students must also have a B or higher in their math class and also be registered for Pre-Calculus or Calculus at the same time. (It depends on the Physics course the student is taking.) If it were this way, I wouldn't have to spend so much time teaching students mathematics concepts, but instead to be able to really teach them physics concepts.

After looking at Midwestern state's course registration, I looked at the one for my new district. What I saw wasn't prerequisites or requirements, but instead recommendations. The recommendation for Physics wasn't Chemistry but instead was Biology. The recommendation for the more advanced physics course that I teach was again Biology. There was no math recommendation. In the reading it says that it would help if the student had Algebra 2 or be enrolled in it concurrently, but not that it was required. This course taught in the Midwestern state made it a requirement that students take Algebra 2 with a B or better before taking the course.

The second thing I saw was that the grade level suggestion for these students in that class was 10-12 grade. They are allowing sophomores to take the course, even when they might not have had Algebra 2 or even Chemistry yet. There is no clear path for what the students should take for science. All that is being said for them to take is biology, and two additional science courses to be taken. Teaching any science content is already hard, but to teach physics on top of the other content, like Chemistry and mathematics, that is needed to pull from makes the job even more difficult; the students feel as if they are taking two classes in one as they are trying to catch up.

I was frustrated after seeing this, and I also heard many of my colleagues voicing the same thoughts I had. How can I truly help my students understand the Physics content if they have not yet learned the foundational skills and knowledge that I need them to build on? How can I truly be successful as a teacher if I have to lower my standards to meet student needs by not getting through all my content, and by curving grades by giving B work an A for students who might never take physics again, or even for students who might move onto the next level of physics? I know I can teach the basics of physics from a purely conceptual point of view without mathematics, but then I will be missing the state standards that are set for them using mathematical equations. How can I truly teach students and prepare them for whatever path they take when they are lacking the mathematical skills needed to help learn the content to the full extent?

After this, I looked at some statistics throughout the United States after this. Internationally, the United States continues to be lower in math and science scores compared to our other competitive countries (Buddin, R., & Croft, M., 2014). When I looked at states individually, however, there were certain states whose test scores were on par with scores internationally. The Midwestern state I'm from is one of those states that is testing on par with international scores. After I saw that, I wondered if their scores are higher because they have set course requirements and have set paths for students to take. They have those requirements for students to take certain classes, compared to other states that don't have the requirements.

So, if there are states succeeding in ranking high internationally in science, what is the difference in science education in those states and in others? I looked at all of the educational data in different states and saw one thing in common: they had a math requirement for their science courses. Often these requirements are hard to find. For example, for my home state, there is not a required math course for Physics *per se*; however, Algebra I is a requirement for Biology, Biology is a requirement for Chemistry, and Chemistry is a requirement for Physics. That is how the math ends up becoming established for the other classes. As all of the states with high math scores have a math requirement starting as the student enters high school, I kept thinking to myself, "Why don't all states have this? Don't the policymakers in those states know how important it is in the content? This is how I came up with my research question, "Does Mathematics Level Affect Student Success in High School Physics?"

I became interested in this topic after seeing students in a new state and their mathematical ability before taking physics. Many students come into the class of physics with the idea that they are good at science, and they like science. Within the first few weeks, I see students start losing interest in physics as they feel it is a class where they have to do a lot of work as they are not only learning physics but also learning the mathematical skills they are lacking. I really think that students will appreciate and enjoy physics more if they didn't have to worry about learning mathematical skills they were lacking. I feel like seeing the true ability of their mathematical skills, and what they are truly able to do with physics is something that can be seen, and a correlation between certain mathematics courses having connections with physics.

Summary

After moving from one state to another, I saw discrepancies between my students. I figured out that the discrepancies are due to not the content, but instead the requirements students need to be able to take my class. I saw that, unlike my home state, there were no prerequisites to take a physics course. The last state I worked at ranks internationally in science along with a few other states that also have math requirements, so I wondered why it was the case not here to see if we really do need a math requirement. Why do they not see the importance of having math requirements for students taking high school physics? Does mathematics level affect a student taking high school physics?

In Chapter 2, I will examine science courses in general, the United States Physics Education History, the problem of mathematics and physics, mindsets of people as well as an educational polity to understand more of why it is important to have a requirement. You will see how some states are doing better than other states in terms of testing within physics and mathematics, and these are the states with the correlation connection and mathematical requirements in place. You will see the process and the whole idea and understanding of what some of the children, parents, and politicians are thinking when being confronted with science education.

CHAPTER TWO

Literature Review

Introduction

There are many people that believe that science and mathematics are the future of our economy and that we need strong skills in both mathematics and science. Then why is there not more of a push to have mathematics requirements for high school science courses in all states? Why are there no policies for it? *Does mathematics level affect student success in high school physics?*

The United States as a whole is lacking in ranking internationally with other industrialized countries in mathematics and science (Ravitch & Cortese, 2009; Kerr, 2016). The nation is constantly coming up with new ideas that we need to implement to better assist students and close the "gaps", but instead of improving, we seem to continue falling more and more behind the other leading nations. How is it that we used to be on top of all nations in the fields of science, and now are falling behind? Looking at the history of science education, we can start to get an idea of what it was like in the past, and what has changed throughout the process to get where we are today, as well as see what continues to not change, but still have debates over.

Looking at the history of physics instruction in the United States, there is a pattern and sequencing that ends up appearing about how things are taught within science education. We can see that science content curriculum standards have not been changed in 20 years (Ravitch & Cortese, 2009). Science scores have improved in elementary schools, but not in the high school science courses (Kerr, 2016). After looking more into the higher-level courses and seeing the reason why physics is the way it is, we were able to see a relationship between mathematics and physics. We see that many people are talking about those two things interrelated and how it all ends up corresponding. Seeing the relationship is important to be able to raise standards across the nation in physics.

When students even hear about mathematics and physics, they start to think negative things about it, which ends up giving them a certain mindset. This is how the numbers of interest in science and mathematics have lowered throughout the years. Also due to the parents' mindsets that their children are learning too much, it ends up lowering the standards the students need to be at, giving the teachers the mindset that students do need mathematics requirements before taking physics as they cannot do it (Landauer-Menchik, 2006). These mindsets end up playing a huge factor in policies as their mindsets end up creating the policies that are needed. Depending on where in the country people are located determines what students end up having as their policies. Most of the policies that are currently in place are graduation policies encouraging more students to take more mathematics and science courses to graduate, but not exactly on what courses to take. There are some states that have policies requiring certain mathematics courses being required before taking certain science courses, establishing a relationship between the two and requiring that mathematics skills to be remembered and used in science courses. But we are able to start seeing all into what is playing into effect into mathematics and physics.

Science Course Sequence

Now one of the main questions on asking why we're falling behind has to do with how are students learning the upper-level sciences in high school? Students now have many choices on how they want to learn science, and what sciences they want to learn about as many states require at least three years of science courses. Traditionally, before 1900, physics was a required course for students to take, although many students had left schooling before taking the course (Otero & Meltzer, 2016). Even in 1860-1884, physics was offered for students to take in 12th grade if they reached that age in school as it was such higher-level thinking (Meltzer & Otero, 2015). There were even many college professors who taught physics teaching or helping out high school physics teachers as it was such higher-level thinking that they thought it was necessary to properly help students learn the material to be successful in college. That changed in the 1920s as the government stepped in and started seeing the importance of high school education.

They agreed that the best way for students to learn science in high school was the Biology first approach. Many believe the reason why is because you learn about Biology, the overview of living things, then Chemistry, why the living things live, and then Physics, the explanation of the world around us (Liu, 2010). Not only did they believe that this made sense as it went more into detail about things already learned about in the previous subjects, but it was also the idea that students would build more mathematical skills that they need for physics.

There is another view of how science should be sequenced in high school. Since 1990s, the American Association of Physics Teachers (AAPT) along with other physics teachers have pushed the belief that science should be taught having Physics First, then followed by Chemistry, and lastly Biology (American Association of Physics Teachers, 2009). This is often referred to as Physics First, “physics-chemistry-biology” sequence (PCB), “early high school physics”, or the “cornerstone to capstone (C to C) program (Popkin, 2009). The Physics First curriculum goes past the topics covered in most physics curriculum as it covers the standards and goes beyond covering quantum ideas that are able to give an introduction into Chemistry (American Association of Physics Teachers, 2009). The push for this new version of science sequencing is to help update the level of modern understanding in chemistry and biology as to understand modern molecular biology, “students need a solid background in both physics and chemistry” (Popkin, 2009).

The Physics First curriculum not only pushes to update to help student understanding in biology and chemistry, but it is also believed that ninth-graders do not have as many of the misconceptions that 11^{th} and 12^{th} graders have about physics, allowing for less confusion when learning the material (American Association of Physics Teachers, 2009; Popkin, 2009). Although many physics teachers believe that this approach does not allow for the equations to be taught as ninth-graders lack mathematical skills and mathematical terms to learn this way (Smith & Washton, 1957). Although physics includes having mathematical terms within its curriculum, the physics first curriculum does not have as much of an emphasis on the mathematical skills, but instead is more focused on the physics content for students to understand more by doing more investigating and inquiry-based learning. The idea is to expose more students to physics, since it currently has a negative connotation and currently does not have many students taking it in high school (Cavanagh, 2006). They want to emphasize building students' "deep understanding of a relatively small number of core concepts, setting clear objectives for expanding that knowledge, and having them conduct investigations to reinforce their understanding" (Cavangh, 2006). According to the American Institute of Physics (AIP), only 8% of private schools and 3% of public schools implemented this curriculum in their schools (Popkins, 2009).

Now these are not the only paths that students are able to take now when entering high school. Some states allow students to choose what science they take and in whatever order they seek, while still having to take a Biology, a Physical Science course, which can be Chemistry, Physics, or a class that has both, and another science course in order to graduate (Lewisville ISD, 2017). Students may never have taken a Chemistry or Physics course by the time they graduate high school as there are other science courses offered today include Integrated Physics and Chemistry (Physical Science), Environmental Science, Earth and Space Science, Aquatic Science, Astronomy, and Anatomy and Physiology. This allows more students to then avoid taking physics as they do not believe that it is needed, or it is too hard to take (Veloo, Nor & Khalid, 2015).

U.S. Physics Education History

In the early 1800s, in the first of high schools, courses called physics were introduced as part of the curriculum being taught as physical phenomena (Otero & Meltzer, 2016). As time went on, physics continued to be taught as it was seen to be important, but it went through many reforms on how it was going to happen and how it should be taught. A lot of this had to do with how physics should be taught as well as how physics teachers should be trained. In the early 1880s, it was seen that they wanted students to be trained to have the "habits of accurate observation and of precise and clear reasoning" (Otero & Meltzer, 2016). This is when hands-on laboratory activities appeared in high schools. It was the idea that they wanted students to learn through experience to be able to draw inferences for themselves based on what they experienced rather than being told. They wanted to train future scientists to think for themselves and learn through experience as that would allow him to start to think for himself.

Science education in the United States wasn't made a bigger priority until the 19th century (Nearor, 2012). It was around then that there was an increase in high schools, and more general science courses being offered more specifically for those who were not capable of doing physics or chemistry as they were considered "hard courses". That was also the time where there was more of an emphasis on "science in everyday life", as there were more students staying in school longer and getting more education. This was then when a "growing gap between the skills needed for desired physics instruction and the actual, limited preparation of typical physics teachers" (Otero & Meltzer, 2017a). There was becoming more students taking high school courses, creating more students to take more science courses, with not enough teachers with the qualifications and knowledge teaching the curriculum. It was then that physics was taught to help oneself think and to catch more of “the spirit of inquiry” (Otero & Meltzer, 2016). The course was more to help people learn more about physics to help them learn to deal with the new technology they were dealing with in their life than to really learn more than to learn the concepts of physics (Otero & Meltzer, 2016). This caused some serious concerns especially after World War II as there were teacher shortages as many physicists were pulled in to help win the World War (Otero & Meltzer, 2017a).

In the 1960s, the government started to get involved in the development of the science curriculum in education. They created many federally funded programs to have universities to help train physics teachers to be able to educate them as well as to spark more interest in science, technology, engineering, and mathematics (Liu, 2010). It was because of the Space Race and Cold War that there was more of an interest. They wanted to make sure that students were learning things to be able to help prepare them to go into physics as a career to further our advancement in space, technology, and engineering once we became the top. In schools, they worked more on improving the physics in teaching both the theories and improving students’ understanding as well as in the inquiry of science to help further more of the learning. It was during this time that they realized they needed more interventions to help train high school teachers on how to teach physics.

Physics seemed to be the course that had roles within its content that could “best play in preparing students for a changing world” (Strassenburg, 1978). It was why it was a course that was considered to be important and started to continue to be as it was the introductory course for future scientists and engineers. Since the 1980s, there has been a steady increase in enrollment in high schools' physics (Otero & Meltzer, 2016; Otero & Meltzer, 2017a). More of these courses however seemed to be moving more away from the mathematical and were to be more conceptual, as it was now serving a variety of students who were both going down the path to be a physicist, as well as other paths. The curriculum started to "emphasize the qualitative descriptions and minimize the use of mathematics contributed to the rise in high school enrollments" (Otero & Meltzer, 2016). There seemed to be more of an emphasis on scientific inquiry and the nature of science, but without teaching it to any specific subject matter (Otero & Meltzer, 2016; Otero & Meltzer, 2017b).

Now it is true that "not everyone needs to understand science as a scientist does, but a large majority must understand as citizens who have enough science savvy to make intelligent decisions" (Meltzer & Otero, 2014). The belief that science should be taught in schools so people have an understanding and are more accurately informed about the different things influencing our world and politics has been around since the 1860s, as we have seen. Yet there has been more of notice that much of the physics teacher quality is what needs to be raised. As it has been said, the United States has been losing the lead in the mathematics and science world as the standards that are currently being altered to help bridge the gap by revamping and addressing the concerts on the content being taught in our schools (Kerr, 2016, Landauer-Menchik, 2006; Buddin & Croft, 2014). This has caused a major look at all realms to see what is affecting this. As "the preparation of qualified physics teachers has failed to keep pace with a dramatic increase in the number of high-school students taking physics. Consequently, more students than ever before are taking physics from teachers who are inadequately prepared" (Otero & Meltzer, 2017b). As we want an emphasis in science classes, especially physics, we need to look at the teacher qualification on it to see the importance of how it is affecting our nation.

Now through Every Student Succeeds Act (ESSA) (2001), there are being more changes to help increase the amount of physics teachers in the nation as there seems to be a shortage (Otero & Meltzer, 2017b). As we want to increase our rank, and continue to be on top, it has to start with getting more teachers that we have a shortage of into teaching those subjects. Yet with making it to have more teachers, what ends up happening is that it "provides legal justification for decreasing or minimizing teacher requirements, including content-area requirements for teachers in specialized subjects such as physics. The practice of relaxing physics training requirements for people who teach physics has informally persisted as long as the subject has been part of the public-school system -- and it has been bitterly and consistently criticized by physicists" (Otero & Meltzer, 2017b). This is how teachers could be allowed to teach physics without having to take any physics or mathematics undergraduate courses, yet still be teaching the content (Otero & Meltzer, 2017b).

It is because of the evolution of physics and how fast it grew to be part of the education system, and still seems to change its role that is important to consider. The debate in the literature focuses on if physics should be a quantized content or a conceptual content learning course. The debate also focuses on how teachers who teach such courses are qualified to do so. It has been said that physics could be taught in a conceptualized manner with very little mathematical equations or skills, yet that calls for more laboratory instruction, which then calls for more laboratory equipment for students to use. Due to many school budgets being minimal, it is hard to keep this alive in schools and to continue the learning through hands on experience. Since there also seems to be only "30% of US physics teachers that have a bachelor's or master's degree with a major field of study in physics", it raises the question of which teachers are able to teach the content effectively if they themselves don't know the content at a higher level (Otero & Meltzer, 2017a). The other 70% of US physics teachers are then science teachers who were teaching another science, or have a secondary science licensure who are then put into teaching physics (Otero & Meltzer, 2017a). In some states, they even have teachers who are currently teaching physics certified in both mathematics and physics (Otero & Meltzer, 2017b). Due to the fact that 70% of US physics teachers do not have the full background knowledge to teach physics, many do not know the most effective way to be able to teach physics. Many try to teach physics through the knowledge of mathematics based off of their understanding of mathematics and hoping that the students also understand it that way. These teachers often teach the concept and then use the formulas, and equations to help back up their point of the concept as they have a hard time explaining the concept another way to their students (Smith & Washton, 1957). Many of the physics teachers do not know how to teach the mathematics that is used as they are not taught math education within their training, but rely that their students do know, or try to teach based off of how they were taught (Otero & Meltzer, 2017b). This is often the way that the teachers prefer, but not the easiest method to learn by the students. This is very different from what national organizations intended when they tried to put together the standards on what all should be taught in physics, and how science should be taught to the students (Kerr, 2016; Otero & Meltzer, 2016).

As physics is the course to learn skills to build off of, that many colleges look for, and even employers in the past, it is an important class, which is why we see growth and more of a need for physics teachers. Due to the shortage of science teachers, many science teachers are not prepared to teach physics in a purely conceptual way. In order for this to happen, more training and equipment is needed to be invested. If physics education wants to continue the way that it is going, with not as much equipment or not much teacher preparation, then more mathematical requirements need to be in place to help the students have less frustration when taking the class. Some sort of reform needs to happen to be able to help teachers be less frustrated with students, and students less frustrated with teachers as physics can help students learn critical thinking and problem solving, accessing, evaluating, and analyzing information, as well as dealing with real-life application of information (Kerr 2016). Through this class, many skills are learned that are needed to help keep the United States near the top in Science and Technology amongst other nations (Ravitch & Corese, 2009; Kerr 2016). Yet to get many of these skills, the teaching needs to be taught in a way to reach all students. Due to a limited number of physics teachers with physics background, it creates a barrier to really help students grow more into these skills without a proper starting point for all students. By having a starting point, where all students have learned the same education, it can create more learning, and more of these skills being created to help our future in technology and science. However, it seems the common factor that has been an issue for the past 200 years has been the same, the need better teacher preparation programs for high school physics teachers as many physics teachers start with having a different background in teaching a different science (Otero & Meltzer, 2017a; Otero & Meltzer, 2016).

The Problem of Mathematics and Physics

“Physics and mathematics are two areas of intellectual activity that have been deeply interwoven throughout the long history of science and yet they represent two separate entities” (Vinitsky-Pinsky & Galili, 2014). It has been a great philosophical debate between philosophers, mathematicians, physicists, historians, and educators. Mathematicians and physicists pursue different goals, yet “mathematics is essential in physics problem solving, although the “language” of mathematics in physics does not coincide with the one used in mathematics class” (Vinitsky-Pinksy & Galili, 2013). Physicists use the skills learned in students' mathematics courses to help interpret the physical meaning that they have discovered to make sense. It has been seen throughout history as Isaac Newton “regarded geometry as a branch of mechanics” and that the creation and development was linked to the needs of physics (Kapucu, Opal & Simsek, 2016). The “aim of the mathematical physicist is to find that abstract structure which has the same essential properties as the particular physics structure which he is studying” (Sharma, 1982). This means that it is using the knowledge in one field to help make meaning in the other field through the similarities seen in both fields.

Mathematics is not only seen in science courses, but is being seen in many subject areas (Hart, 1981). It is mostly in the science department one hears the complaints about students. It is not the mathematics departments' fault as they have different ways of viewing mathematics, but also the fact that students have a difficult time learning mathematics (Hart, 1981). Yet because "physics and mathematics lessons are tightly related disciplines" those teachers are able to see more of the problems that are arising with their skills (Baska, Alev, Karal, 2010). The areas where teachers have seen the most problems students have with their mathematics skills are in decimals, fractions, rearrangement of algebraic formulas, and operations (Hart, 1981; Hart, Turner, & Booth, 1982; Stein, 2001; Baskan, Alev, Karal, 2010).

The biggest problem that has been seen is that mathematics and physics are "perceived as different and unrelated lessons by students and they study these courses separately" yet they often use the same skills or similar types of problems and problem solving skills within the class. (Stein, 2001; Baskan, Alev, Karal, 2010). The reason why it creates an issue is because "students understand abstract concepts in mathematics with the help of science, and they deeply understand science thanks to mathematics" (Baska, Alev, Karal, 2010). If they don't keep the two separate but use the two in each of their subjects, they can actually understand more and get more out of it. A lot of the time a science teacher may try to teach some of the mathematics but does not know the correct terminology that is now used, or the right way that it is taught, creating a barrier and distress between students and teachers (Hart, Turner, & Booth, 1982; Hart, 1981).

Physics was first taught without mathematics as there were no physics books with the mathematics within it (Kapucu, Ocal, & Simsek, 2016). Yet it is known that mathematics plays a role in physics as Galileo has said that "the laws of nature are written in mathematical language" emphasizing the importance of mathematics (Kapucu, Ocal, & Simsek, 2016). Back in 1915, Griswold noted that "no real progress in science is possible without mathematics" (Griswold, 1915). Physics uses mathematics as a language to explain the natural world; its use of numbers, variables, equations, and graphs differs when comparing it with mathematical applications, yet it is still needed to be able to truly learn the physics (Kiray, Gok, & Bozkir, 2015; Liu, 2010; Meltzer & Otero, 2014; Michelsen, 2015). So, physics needs mathematics to be able to make sense of what is happening in the physical world around them. Although books were taught without the mathematics, it keeps going back to having the mathematics in it to be able to make more sense of the world and make more sense of this abstractness that the students are dealing with (Griswold, 1915; Hart, Turner, & Booth, 1982; Baska, Alev, & Karal, 2010).

Next Generation Science Standards (NGSS) have crafted their science standards to include using more mathematical computations and terms within it (NGSS, 2017). Within the new standards, they have the expectations that the high school level use scientific practices that involve "developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; and to use these practices to demonstrate an understanding of the core ideas" (NGSS, 2017). The belief is that even if the students do not have the required mathematical knowledge already, the science teacher will be able to teach the missing knowledge along with the physics to help the student be able to succeed (Stein, 2001, & NGSS, 2017). They would like the physics teacher to not only teach the science concepts, but also the mathematical skills that they also need to be able to help them understand the physics concepts with it.

“Most high school physics courses are now - and have always been - taught by teachers who were never specifically prepared for that job, and who have not had the requisite preparation recommended by physics educators (that is, a major or minor in physics)” (Meltzer & Otero, 2014). Many physics teachers who lack the physics background have a harder time teaching physics as they do not have the content mastered and think the best way to teach it is through their previous knowledge in mathematics as it can be easier to understand it in that way (Bing, & Redish, 2007; George, 2012). Yet to truly teach physics, a teacher needs to teach the concepts and relate things that they are learning in physics to the concepts they have learned in mathematics (Meltzer & Otero, 2014; Corkin, Ekmekei, & Papakonstantinou, 2015). As many physics classes, even conceptual physics courses, are taught with very basic algebraic knowledge for students, the knowledge and skills are still needed to a true understanding in a physics class (Stein, 2001). Even within the Physics First approach, they still believe that mathematics should be taught within the physics curriculum, but how much depends on the student’s academic level of mathematical knowledge to be able to help them succeed (American Association of Physics Teachers, 2009). According to Cavanagh, “many physics topics require some math, but not too much, and are appropriate for 9th grade… other concepts which generally depend more heavily on algebra and calculus can be avoided at that grade level" (Cavanagh, 2006).

It is often hard for students as they see the two as separate entities and classes that need to be kept separate as students see mathematics as a challenge course, often getting discouraged when called on to do mathematics in science (Hart, 1981; Kapucu, Ocal & Simsek, 2016; Nix, Perez-Felkner, & Thomas, 2015). "Often in science the mathematics needed occurs as an isolated and temporary phenomenon in a non-mathematics setting," which causes many students to remember that one way of memorizing the process instead of understanding the process (Hart, 1981). In mathematics it "tends to be of the same type of problem over a period of time with considerable practice on one and only one aspect" (Hart, 1981). When students are called on to make the two related, they have a hard time really understanding what is going on, and just want to memorize instead of truly understand what is going on. "While it is clear that learning physics requires mathematical knowledge, the exact dependence of physics education on mathematics should be refined in order to ensure that teaching effectively supports students' understanding of physics" (Vinitsky-Pinsky & Galili, 2014).

The reason why understanding the relationship between the two disciplines and the problems within it is important because it all goes back to the question "Does the mathematics level affect student success in high school physics?" Physics was initially taught without mathematics when the first textbooks were made; however, advancements in science have not happened without mathematics. Without having mathematics in the courses, students will get the wrong idea about physics.

Another reason why we need to try to understand this question is that many physics teachers do not have a background in physics. Due to this, it makes it challenging for many of the teachers to teach their students the mathematics background for them and sometimes even rely on them understanding the mathematics to then understand the physics through mathematical relationships of variables. Since many students are exposed to basic algebra skills and relationships of variables since elementary, many teachers without the background try to rely on this to help drive their teaching of the material (Stein, 2001). This then makes it easier for teachers to teach it if they don't know all the content but makes it harder for kids to learn if they don't like mathematics, and often discouraging them in physics as well. Understanding that students have trouble with mathematics makes it easier to understand what is going on with the data and seeing that if there are a relationship and a need for a requirement. Knowing that mathematics is the language of physics many teachers use mathematics in their teaching and that it is in the language of the curriculum, we can see how their mathematics level affects their success in their physics course.

Mindsets

There have been many articles that have been released that continue talking and wondering why the United States is behind in mathematics and science standards. Educators. Policymakers and even CEOs of major corporations believe that mathematics and science standards are not where they need to be with students not performing at that level. Even as Gates said in 2005, "we will keep limiting - even ruining - the lives of millions of Americans every year" unless we design our high schools to "meet the needs of the 21st century" (Johnson, Arumi, Ott, & Remaley, 2006). It has lately been predicted by many educational agencies that unless we start raising our standards in high school, instead of lowering them to decrease the gap, we will lose the leadership that the United States has in science and technology.

The mindset of educators, policymakers, universities, and CEOs believe that states need to raise standards so that the United States will continue to be competitive in the mathematics, science, and technology fields. How they saw fit to raise these standards was by raising graduation requirements. In 2013, there were 37 states that "require at least three years of science courses to be able to graduate" (Budding & Croft, 2014). In many northern parts of the United States, they have raised their graduation standards for students that they must take mathematics: Algebra I, Geometry, Algebra II, and additional math, and three years of science: Biology, Physics, or Chemistry, and additional science (Minnesota Department of Education, 2014; Michelsen, 2015; Meltzer & Otero, 2014; Edsource, 2008). These were created to be able to help "contribute to the development of the workforce of the future" as many jobs are becoming more science and mathematically founded (Landauer-Menchik, 2006; Edsource, 2008).

Although high schools only require three years of mathematics and science courses across the United States, most four-year universities require students to have four years of mathematics and science courses (EdSource, 2008). The reason for this is because most of the fastest-growing jobs, or jobs in high demand, are jobs that require advanced mathematics and advanced science background (Cunningham, Hoyer, & Sparks, 2015). Although not all of these jobs require four-year degrees, like electrician or auto-mechanic, they still require mathematical and technical skills that you learn in advanced science courses (EdSource, 2008; Michelsen, 2015). Many states have changed their standards to require more science and mathematics courses but haven't changed any of the curricula on what it is that they are learning. Science curriculum has been said to have been "diluted since students were provided with many opportunities to avoid challenging courses, reduced homework, and lower graduation requirements" (George, 2012). As many students are now offered more options in science courses to take, it means that fewer students are taking higher-level science courses that other countries are requiring students to take, like physics. This means that students are no longer learning the challenging sciences that help the world continue to move forward in the new industrial age, and instead of learning simpler things, making the United States fall behind other countries (Ravitch, & Cortese, 2009).

The question, "Does the mathematics level affect student success in high school physics?" still stands as many states have raised the standards to require more science courses to be taken, and most schools only offer biology, chemistry, and physics. This means more students will take physics if there are no other options available, yet not all students have the advanced skills developed yet if the proper background knowledge has not been learned. This means that the teachers are more responsible for teaching this background knowledge to help develop those skills to help them be more successful in the courses.

Although educators, CEOs, and universities believe that the content standards need to rise, the mindsets and views of parents and students are different. "While neither parents nor their children underestimate the role of science and math will play in the future world of work," they don't think that it is affecting their own lives (Johnson, Arumi, Ott & Remaley, 2006). Many believe that their child is being prepared and will be ready for college or work when the time comes, even when that is not the case (Johnson, Arumi, Ott & Remaley, 2006). They believe that what they are learning now in math and science is the "right" amount and that there is no need to add more to their load.

Although they are saying what they are learning is "right", there are also some other districts with parents on the district board asking to lower the content standards for their students as they think they are learning "too much, too fast" (DeBuvitz, 2018). Parents even believe that their district or school is learning more than the others, even when they do not compare it themselves to see if it is true. Although this is one area, and it is not compared to other districts or even countries, it is still seen that parents think that standards should not be raised in terms of what they are learning as what they are learning is enough (Johnson, Arumi, Ott, & Remaley, 2006).

Instead, parents believe that more should be done about classroom management, student misbehavior, and societal problems like drugs and alcohol (Johnson, Arumi, Ott, & Remaley, 2006). Parents are more worried about those problems instead of what the future generation is learning about to help keep the United States on top. Because so many things are already being done, and that the United States is already falling behind in standards, they believe that it is linked to these problems instead of the content standards we currently hold for our students being lowered than what they are in other countries (Kerr, 2016; Johnson, Arumi, Ott, & Remaley, 2016).

Many students have the same mindsets as their parents as they believe that more should be done around the classroom to learn more about social and life skills instead of learning more mathematics and science skills (Johnson, Arumi, Ott, & Remaley, 2006). They believe learning those skills does not help them be creative or help them with a career that they might go forward and do in the future (Valenti, Masnick, Cox, & Osman, 2016). They believe that learning higher-level science like physics is not relative to the world that they are in or need the skills learned in that class for their future. Students believe that they are not able to do physics as they need to have higher levels of mathematics skills to do physics when in reality all they need is Algebra II for students to succeed in Physics (Corkin, Ekmekei, & Papakonstantinou, 2015; Kapucu, Ocal, & Simsek, 2016; Kiray, Gok, & Bozkir, 2015).

Many of these mindsets end up hurting as many students will not consider fields in mathematics or science as they believe they are unable to do it or end up disliking the subject due to their lack of skills in mathematics (Nix, Perez-Felkner, & Thomas, 2015). As many students have difficulties with linking graphs equations or diagrams to physics concepts or the real world, they have a dislike for all things related to those skills. They find that they are not able to do it or become disinterested in it altogether thinking it is unnecessary information needed for their future (Veloo, Nor, & Khalid, 2015).

There are many different views on the reasons why students have a disinterest in science. Some believe it is from when they are faced with challenges which they are not prepared for, and some believe it is because of the lack of teacher preparation. Many physics teachers believe that students should have the proper mathematics skills necessary before taking high school physics so that they do not have to teach them the mathematics when coming into taking their class but instead use the skills to help build relationships off of it and relate it to the physics (George, 2012; Meltzer & Otero, 2014). Other physics teachers believe that they can take physics and the required mathematics course at the same time as it helps build off the other to give them skills needed between the two courses (Michelsen, 2015). "Physics teachers often state that their students do not understand physics due to the lack of mathematical knowledge and claim that such knowledge guarantees successful learning of physics" (Vinitsky-Pinsky, & Galili, 2013). This is saying that many physics teachers do believe that a mathematics course is required for students taking high school physics.

Teachers are trained to teach all students within their Zone of Proximal Development, meaning that teachers are taught to measure what is too hard or too easy for their students (Michelsen, 2015). This then has them change their teaching to be able to reach all students at the needs that they need (Hicks, 1997). As teachers are around students and teaching them, they have to make decisions to be able to help their students achieve, and sometimes that includes not teaching beyond the standards, and sometimes not teaching skills they are lacking to be truly able to understand the concepts they are learning (Hicks, 1997; George, 2012). When science teachers were asked what they do in class when students lack mathematics skills, science teachers said that when they "did teach some mathematics it was most often done by rule learning and not with the purpose of understanding the mathematics" (Hart, Turner, & Booth, 1982). Teachers will do what is needed, but they can only do so much to help their students while still making sure they are hitting the state goals and teaching all of the state standards the students are to learn in their content.

As teachers have the mindset that their students aren't able to do certain skills needed when taking mathematics and science courses, they have ended up lowering the standards for students, making it easier for them to pass (George, 2012). This then creates many beliefs that students aren't able to do physics as they have lowered the mathematics abilities, lowering their confidence from taking more challenging courses (Nix, Perez-Felkner, & Thomas, 2015). This is one of the main reasons why Common Core was set into place, to help make sure that standards were high and teachers weren't lowering the standards to adapt more to what they think students can do, when more things might be contributing to their lowering of standards, like their own mindsets (Phelps & Milgram, 2014; Kapucu, Ocal & Simsek, 2016). This then ends up having a greater cause as the SAT standards are being lowered as students are not being taught to the standards they are supposed to as they continue to get lowered and lowered (Phelps & Milgram, 2014).

Many of this mindset that students have lowered mathematical abilities stems from the fact that many of these teachers do not have mathematical teaching backgrounds, and did not have to teach many of these things in the past. "Many experienced teachers may be accustomed to mathematically advanced, self-selected juniors and seniors" (Popkin, 2009). It is due to this fact that many teachers are even against the Physics First approach in their schools as the instructors are then giving students a "watered-down science" (Cavanagh, 2006). The reason why these teachers believe that is because they think that “physics should be taught when students are older and have a stronger grounding in math” (Cavanagh, 2006). Many of these teachers saying this is not of the 30% that have a bachelor’s or master’s degree, but instead many of the other teachers that meet the state’s requirements by having enough classes within the college to be able to teach the subject (Otero & Meltzer, 2017a; George, 2012). This shows that many physics teachers have a fixed mindset about this topic.

If these teachers were given training, and more support either by having more physics classes background or even mathematical teaching background it could help support more of these teachers. American Association of Physics Teachers has urged many school districts to allow for more opportunities for teachers to expand their learning and teaching of physics through more professional development opportunities (American Association of Physics Teachers, 2009). They have also urged districts to help their teachers feel more comfortable teaching the content through inquiry-based learning by providing teachers with more equipment (Otero & Meltzer, 2017b; American Association of Physics Teachers, 2009; Debuvitz, 2018). Many physics teachers who advocate for Physics First believe this should be a push for all physics teachers to be able to better prepare the teachers for students’ questions, as well as prepare them more with the mathematical teaching background that science teacher are not trained with to better equip teachers if more equipment is not available (Otero & Meltzer, 2016; Otero & Meltzer, 2017a).

This then all plays into the mindsets of the parents and students thinking they already have enough learning and things they need to do and don’t need to learn more to be successful. It then goes to the teachers who believe they aren't learning enough to be successful. It also goes farther than that as now outsiders are having the same concerns on if the United States will continue to be on top in science and technology because the mindsets are now that kids cannot do it, yet it is believed they can, they are just not being properly prepared for the advanced courses to help them with those skills. As it has been said that mathematics and science skills are needed for a variety of jobs, so it does need to be learned although students and parents would disagree. Physics teachers talk about how they need students to have those skills before being able to get through all content and to truly teach the skills needed to learn in this class.

Policies

Policies are important in education as they are the guidelines for what is made for teachers to follow. They are made at the federal, state, and district levels, which is made to help the students living in that certain area as not all policies made are perfect for all children. This means that one teacher who has policies for one state may not have the same policies in another state. This was something personally noticed when moving from a Midwestern state to the Southwestern state.

After looking at the graduation standards of a Southwestern state, they were the same as the Midwestern state graduation standards. Many states have increased the mandated minimum course requirements in mathematics and science in hope of increasing the number of participants in STEM-based occupations (Buddin & Croft, 2014; Cunningham, Hoyer, & Sparks, 2015). "In 2013, 42 states required students to take at least three years of mathematics, and 37 states required at least three years of science to expose more students to sophisticated mathematics and science concepts" (Buddin & Croft, 2014). However, there was a difference in the standards of what the students were learning in the content itself.

Although it is great that many states are increasing their policies to require students to take more mathematics and science courses, the issue is that the content being covered is "being lessened or easier to accommodate the various skill levels of incoming students in the course" (Buddin & Croft, 2014). The one thing being seen that is affecting this is because "American students have a math problem" (Kerr, 2016). Because students have a mathematics problem, it creates an issue between science courses, especially physics, as some science teachers now have to teach mathematics on top of their content to scaffold the difference of knowledge and skills between students, which can in some cases lead to content being left out, or not taught to the fullest extent (Stein, 2001). The reason why this is because of the relationship between science and mathematics that was discussed before, which makes it even more important to be addressed.

The reason why the Common Core Mathematics Standards were created was to create "standards for all public-school students in this country regardless of achievement level, they are low standards, topping out at about the level of a weak Algebra II course" (Phelps & Milgram, 2014). They wanted them created so that they know the standards for all students across the country are at the same level, even though they are to graduate with weak Algebra II standards. This was making it the same standards which make it easier to create standards for science by knowing the standards that are being held for mathematics. Because the Common Core Mathematics Standards are not implemented by all states, it makes it harder to know where all students are mathematically (Phelps & Milgram, 2014). Four-year colleges and universities rely heavily on the idea that Algebra II courses are taught at the same level throughout the states (Kiray, Gok, & Bozkir, 2015; Budding & Croft, 2014). Yet when standards in Algebra II are being lowered, it affects their abilities in other classes, like advanced science courses (Ozgen & Bindaka, 2011; Kiray, Gok, & Bozkir, 2015; Michelsen, 2015).

As colleges want to see students take advanced science courses, like Chemistry and Physics, as they want to see them use real-life application of information, get more critical thinking and problem-solving skills, as well as learn how to effectively assess, evaluate, and analyze information (Cunningham, Hoyer, & Sparks, 2015). But students also need the necessary mathematics courses to help them with understanding the courses at the correct content level (Kiray, Gok, & Bozkir, 2015). For example, in Physics, students need to be able to do algebraic formulas, graph data, derive formulas from graphs, use scientific notation, be able to use dimensional analysis, applied problems, and add vectors in two dimensions (Kapucu, Ocal, & Simsek, 2016). Now there are some things that are able to be taught when learning, but there is no time to teach the whole mathematical concept and why one would use it. Instead, the teacher teaches it as a refresher skill and moves on teaching the new content. The whole idea is how to apply the mathematical skills that have already been learned and mostly mastered, if not completely mastered. Some schools and states require these as prerequisites before they take the class as they see the importance of being able to build more skills in the science courses in these advanced classes instead of learning it all at once (Cunningham, Hoyer, & Sparks, 2015; Saint Paul Public Schools, 2017; Lewisville ISD, 2017).

In 2013, Next-Generation Science Standards were created for many states that end up incorporating mathematical skills in the use of all science courses (NGSS, 2017). Within this, they believe that mathematics and science should be used hand in hand to continue to improve and encourage students to go into engineering fields (NGSS, 2017). Depending on the school district readers' interpretation of the standards, the content can be taught to different levels between school districts within a state. NGSS is trying to have the standards taught at a higher level and incorporate more of the real-world problem solving into the learning to help make it more relevant to students (Ravitch & Cortese, 2009; Ozgen & Bindaka, 2011). This is wanting to help the nation get on top again as we are falling behind internationally (Ravitch & Cortese, 2009; Ozgen & Bindaka, 2011). The states and school districts with the already existing policies are creating great students who are prepared for college and university, but they are dealing with peers from other countries that are now testing better than America is in mathematics and science standards (Kerr, 2016).

As standards continue to be lowered, the issue that seems like a repetitive cycle of lowering standards is now lowering our national rank with it. Yet within some parts of the country, changes are being made, and those states are ranking internationally higher than the United States as a whole is able to rank (Kiray, Gok, & Bozkir, 2015; Cunningham, Hoyer, & Sparks, 2015).

There are certain states in the United States that are able to rank competitively with other international countries with their mathematics and science standards as a whole, meaning that many of them are competing with people around the world for great jobs and places into great schools, while other states are still struggling with closing the achievement gap (Kerr, 2016). The idea behind Common Core was not to dictate what all states have to teach but to get a more grounded idea of what the United States is teaching to all of their students (Ravitch & Cortese, 2009). Some states decided not to go with Common Core as they had standards that were higher than that, while other states didn’t want Common Core as they have to lower their standards to close the gap between minorities and white students (Phelps & Milgram, 2014). The issue that is constantly being noticed is that many students continue to fall behind in mathematics, which then falls into science subjects, especially physics.

These differences in policies and lowering standards are not helping the country. The policies are allowing more students in the United States to graduate, but at what cost? It seems that doing so is making it harder for more students to be able to pursue more and work in the higher fields in better jobs that are science and mathematically geared; however, those jobs seem to be going to other people from other countries, making us fall behind even more because we want every child to be able to learn content, that is meant to be hard and tough, and is not meant for all students to learn at the certain level that is demanded to keep the country on top.

The other policies that always have seemed to be a problem are the policies made for physics teachers. “Physics education reform has been largely on classroom-based innovation rather than on the more political and institutional change required for long-lasting reform" (Tobias, 2000). When looking through physics education history, it has been always a short-term goal fixing at this instant instead of long term goal solutions. Now educational policies already take a while to implement because results aren't seen right away, yet they continue to be changed so fast before any change is able to be seen (Otero & Meltzer, 2017b). According to Otero & Meltzer, "the historical record reveals that discussions by science educators of the 1800s and early 1900s featured many of the same ideas found in today's national reports and debates on science education" (Otero & Meltzer, 2017a). This shows that many of today's educational debates in physics have still been the same debate for over 100 years, and the policies made to help implement these were not addressing the issues science educators were bringing forward or helping cause change to the issues they were discussing. Most likely, the change was brought forward, and before being fully implemented, it was changed again before anything new could happen.

This would be the same thing if a mathematical requirement was placed for students before taking physics. It would take a while to implement it, and for results to be truly seen with an increase of standards and teaching more. Once implemented, teachers would continue to teach their way and just see higher grades. Instead of raising their standards right away, they would slowly and surely do it to help students learn more. Again, it would need time for the change to play into effect to create higher standards and give more help, as all policies have needed.

The other reason why seeing this is important is that this might not be the first time that this educational issue has been presented before. It has been shown that science teachers come forward with problems, only to have something be put in place that doesn't necessarily take full effect until down the line, but always gets changed before that. One thing seen whoever, is that science teachers need to be persistent, and those who create the policies, need to be open to more listening and collaborating instead of making the decisions, but not seeing it through, as change needs lots of time to take full effect.

Now ESSA, Every Student Succeeds Act, was put into law in 2015. The contents of it are still being implemented today, which will take some time. However, in Title II of ESSA, it ends up "providing legal justification for decreasing or minimizing teacher requirements, including content area requirements for teachers in specialized subjects such as physics. The practice of relaxing physics training requirements for people who teach physics has informally persisted as long as the subject has been part of the public-school system - and it has been bitterly and constantly criticized by physicists" (Otero & Meltzer, 2017b). That means that standards of high school physics teachers are being lowered even more than they are to be able to fill the shortage of physics teachers. This law policy can make it that physics teachers may have never taken a college-level physics course, yet still, be teaching the content to high school students. Now it has been talked about throughout physics history of having high school physics teachers who don't know physics as well as physicists, but this new policy is making it so the teacher may have no knowledge of physics at all but still be required to teach it.

Now as much as the standards should be raised, the lack of physics teachers is the government's main concern to be able to help more students be exposed to it, although it may not be at the level it needs to be taught at. However, it is another reason to need to have the mathematical requirement before students take physics as physics teachers might be only to truly teach physics to the best level through relationships seen in mathematics. Now not all of them will have a mathematical background, making them teach it even harder, which is why they rely on the students already having those skills. If they don't have those skills, it makes it harder for them to teach it.

Summary

The United States is falling behind being the leader of science and technology. Many people are wondering why this is happening. As we look through science history, we see that many things have been changed and viewed as important within science education. Through the years, it has been seen that physics education has had the same fights going on for centuries, yet with not the correct outcome ever coming from politics. It has also been seen that mathematics is interrelated with physics, unlike what many people think. This sometimes discourages students from taking physics as they believe it is a hard class that is not able to be done without higher mathematics courses like Calculus. It is true that they need to have a mathematics background and skills to be able to learn physics, but you do not necessarily need higher mathematics classes to be able to take the course.

As many students get discouraged from taking physics because of their lack of mathematics ability, many parents believe that their students are already learning enough and do not need to learn more science or mathematics. They believe that it is already hard, and we need to continue lowering the standards than what they were in the past as they are learning too much. Many educators, CEOs, and politicians believe that we need to keep our standards up, and not keep lowering them, but also finding more ways to get students more involved in mathematics and science to be able to continue being ahead in science and technology. One way that is able to happen is through policies like having mathematics requirements for students in order to continue learning more and keep high expectations. Otherwise, things will keep continuing to lower to the point that colleges will no longer understand what the true meaning behind their grade is or even their ACT or SAT score.

Now knowing all of these things, it really makes me wonder why there isn't a mathematics requirement for students taking high school physics courses already in place. If educators and policymakers have to lower standards because students do not have the skills needed for the course, why not have requirements put into place so all the standards are still able to be taught and met?

After seeing that in states where they are doing better education-wise, there is a relationship between mathematics and physics, I will be conducting a mixed methods research with students taking physics. This research will help see the raw data between the skills of mathematics and physics as well as the students' mindsets of their data. This data will help see what teachers are doing to help their students, how the student's mathematics skills are, and their mindset behind their testing to understand their motivation behind their studying for their test scores. This research should help them create policies that are in place in certain states and show the importance of having those mathematics skills for taking physics courses.

CHAPTER THREE

Method

Introduction:

Does the mathematics level affect student success in high school physics? If you go ask students, they think that there is no need for math to be anywhere in science courses. If you go ask a physicist, they will say that physics requires mathematical knowledge. It is essential in problem-solving. The "language" of mathematics in physics does not coincide with one used in mathematics class" (Vinitsky-Pinsky & Galili, 2014). Yet depending on the school in which you are teaching, it determines the level at which a teacher would teach physics.

Given the policy decision within my district, my teaching context has physics placed last in the sequence of biology, chemistry, and physics. As I am both a physicist, and a teacher, I say that for this given sequence, there should be a mathematics requirement that is needed for students taking high school physics, yet it is not at all schools. I have decided to do research at the school I am teaching at looking at the correlation of the mathematics course they have taken, the grade received in that class, and the average of their test scores in their physics course. I will not only just take quantitative data of their test scores, but also qualitative data through interviews, observations, and surveys to understand what was being done to participate into the grade that they are receiving in the class.

In this chapter, I will talk about the research paradigm and method that I have chosen to do my research. I will talk about the setting in which the research will be done, so people will understand what type of environment that the students are in and what might be affecting the teachers and the students. I will talk about all those who will be participating in the research and the reasoning behind doing that research. I will talk about the procedure in which I will be collecting the data and the reasons why. I will talk about the tools that will be utilized and how I will analyze the data. All of this will help with understanding the data and answering the question of if there needs to be a mathematics requirement for students taking high school physics.

Paradigm

For the research of this project, I decided to go with a mixed methods research paradigm. Mixed methods research is a type of research method that takes multiple ways to explore a research problem (Michelsen, 2015; Otero & Metzer, 2016). One of the main reasons why I chose mixed methods research is to be able to help overcome any limitations that I might encounter with a single design. There are many things that can affect a student's score on a single test if I was just looking at testing results. This model helped me be able to see what factors attributed to a student doing poorly on one test, but well on others. It also gave me more insight into the type of student they are since not all students are the same. Another reason why I chose Mixed Methods research is that my interpretation was continual and was influenced in stages in the research process as I was taking data throughout the course of a student taking physics at each unit test to see where the students are at, what their view was, and knowing what they learned as some concepts are tough to understand, and not all teachers are the greatest at explaining it. This way I was able to talk about all the other factors going in, and since I was doing it within stages and doing a long study with many people, I was able to really go through the interpretation and talk about what exactly was going on at each stage.

The data is taken from three levels of entry-level physics classes offered by the district, Regular Physics, PreAP Physics, and AP Physics I. Each of these levels had different levels of students taking each of the classes (see Appendix A). I was looking at the data at each level to see if students were properly placed in the correct classes, as well as help find a correlation between what is common amongst the students in each of the classes since they differ based on how much content they cover. This helped me sort through data better as there were students who are in which of the courses and where students should properly be based on their previous mathematics course as the courses differ based on the mathematical skills needed within each course. Because I looked at all the levels as well, I was able to interpret what that means from a teacher’s standpoint on knowing what level they should be at through the help in teacher interviews, as well as the student’s view from their standpoint.

The other reason why the Mixed Methods Research worked well was that the stages I was doing it will not only be looking at their test grades that they get with each unit test, but looking at what mathematics course they completed before taking physics, and the grade they got with it. This told me what level they completed the mathematics course, and at what level of mastery. As physics entails a lot of mathematical skills, I was able to see if the students with the necessary skills of mastery that they received from their math course fulfill what skills they actually have to be successful in physics without going outside tutoring or having to retake any unit test.

Method

The type of research method I used was a sequential explanatory. This "characterizes the collection and analysis of quantitative data followed by a collection and analysis of qualitative data" (Creswell, 2014). It got data from both sides and used one to support the other to assist in explaining and interpreting the findings of the study as there are always things that influence what is going on. It was using the qualitative results to assist in explaining and interpreting the findings of a quantitative study. This served the best to understand what is going to affect the student's performance on their test grade, and what interventions they might have done in order to help their grade.

Setting

The school I did the research in is one of five high schools in a district that incorporates parts of seven cities, and another whole six cities in the suburbs of a southwestern state. This school has about 3,200 students, and 285 staff members in the school, 199 which are full-time teachers. The school is on 53 acres of land, where they have one building that teaches only ninth graders, and another building that teaches 10-12 graders.

Within the student population, 1% is American Indian/Alaskan Native, 5% Asian, 4% Black, 11% Hispanic, and 77% White. Forty-nine percent of the students are female, meaning the majority of the students are male. Of the student population, 7% of the students are economically disadvantaged, where the majority of that percent receives free lunch.

There is a 98% graduation rate at our school, but when looking at state performance of mathematics proficiency, only 56% of our students are testing satisfactory and advanced when taking the Algebra state test. This affected our data as only about half our students are passing the basic Algebra state test, meaning that many mathematical skills are not where they need to be. This affected how science teachers are teaching, as they need to help students build up their mathematical skills just to complete the science skills that they need.

A typical school day for a student involves four periods that are 90 minutes each for the semester. Students get half an hour for lunch that is determined by which lunch they get that is during their 3rd period of the day. This school offers athletics, and some extracurricular activities as one of their class periods, so students may only have three periods in which they have academic courses, and another period which would be considered extra-curricular. These extra-curricular activities also affect other class periods, just like any high school, as they take students away from school early for games or events. This then affects what students are learning in school as sometimes their teacher is a coach, or sometimes they are the ones missing class.

At the school, the science course offered on the 9th-grade campus is Biology. There is no other science course offered for their first year of high school science. Due to the decision that they only offer Biology as a first-year course, the school is under the

Biology first sequence for high school science, meaning that students are to take Physics after they have taken Chemistry. Under this assumption, many students should have taken and passed Geometry, and Algebra 2 by the time they take Physics if they are on the normal math and science track. If they are behind, most students will take Integrated Physics and Chemistry (IPC) after Biology, and then Chemistry to be able to build their mathematical skills for another year, before going into a science course that needs strong math skills.

Participants

The participants of this study were students who took Physics, Pre AP-Physics, and AP Physics 1 (See Appendix A). The order in which all the classes are listed is in order from the most basic content to more advanced content in regard to the physics curriculum since all courses are entry-level physics courses. The reason why the study did all students in all levels of physics is to allow for more data to be taken between all the levels that physics is taught at. This could help the school district see if there are any patterns indicating a relationship between taking certain math courses prior to physics have on student success rates at the three levels of physics classes. The other reason for all the students within these classes is to also know the different levels and to help determine errors in data within the bigger group for having certain students taking courses that they are not prepared for, or even for students who need to be in the higher course but are taking the easier course. This way we can see more of that of data, and see more of what the normal trend is.

Procedure

Before the students came to school, I went and sought the approval from my principal to do this through a meeting. He signed the beginning page of my consent forms and signed a consent form of his own (See Appendix B). From there I sought the approval from my colleagues to interview them as well as use their students to help with my data (See Appendix B). After getting the approval of my colleagues, and once each semester began, I went around to each of the different teacher's rooms who agreed to the study that were teaching physics to tell their students that they are going to be a part of a study (See Appendix C). I explained exactly what the study entails and what it is that they are actually doing. They received parent letters (See Appendix C) that also went into detail describing that their students are going to be a part of the study and what that study entailed. I ensured them that they are not going to be harmed, but instead just study on what exactly they are doing within the process of them taking a physics course.

Once all permissions from parents were received, an initial survey was completed by the students either through paper, or Google Forms that entailed questions about what their last mathematics course completed were, what grade they received in the course, what course they are currently taking, and the student's view on what they thought about mathematics, what they thought about science, if they thought they need math skills in their science course, if they've had a hired math tutor in the past, and if they had a hired science tutor in the past (See Appendix D). These questions were asked to help analyze the quantitative data more accurately as some of the data would have been affected by their attitudes toward math, and if they had hired tutors in the past. These questions can affect how the student's past grade in the earlier class as someone with a tutor could have gotten a higher grade than one who did not hire a tutor, but the student without the tutor could have mastered more skills than the other. I was trying to gather more background information to help see where students were at before coming into their class to see if and how that changed from their current habits.

After the first initial data was taken, different types of data were gathered. Observations of my peers were undertaken to note differences in teaching approach between sections, so I could ascertain what one teacher does that could better assist their students compared to another. I also interviewed the teachers individually with simple questions to get an idea of what their classroom is like (See Appendix E). I also followed up with interview questions with them after each unit to see what they thought of their data results, as well as the student survey results (See Appendix F). This was able to give me more insight into the teaching part and what all had affected their results with this.

Data was collected after each student's unit test. After the student completed a unit, they took a test and completed a survey (See Appendix G). The student's survey entailed open and closed-ended questions that included how they felt about this past unit, how they think they did on their test, what they would do differently if given the chance to restudy and take the test again, did they hire math tutor during the unit, did they hire a science tutor during the unit, did they go to before or after school tutoring with their teacher, or did they go to before or after school tutoring with another teacher within the school? Additional data collected included how the students did on their unit test overall, a breakdown on how they did on the conceptual based questions (multiple-choice, fill in the blank, true and false) within their test, and a breakdown on how they did on the math-based questions within their test. This also gave the idea on what might be affecting their testing data and got more into the student's perspective on what they are thinking and how they are feeling about the test when going through it as students prepare different ways and have different motivation on studying for this class depending on who they are (Hicks, 1997). This was done throughout the course until the course was complete.

I went through the data as it came in and evaluated and interpreted as the year went on. This allowed me to get more of an idea on which units were harder for students, and what seemed to be easier for students to understand. At the end of the course, I completed a final survey on how the students think they did about the course as a whole. I asked them the similar questions I did at the beginning of the year, along with additional questions like what grade they received in this class, and if they think there should be a math requirement needed before taking the course the student was enrolled in (See Appendix I).

Tools

Over the course of my study, I used different tools to collect data, as talked about above. One tool I used the most, besides collecting data on how they did on their tests, included students being surveyed. The reasoning behind doing surveys was to get an idea of how students felt about the content they just learned and how they think they did on the test. It also gave me an idea of what they did to prepare for the test as every student is different and will prepare in different ways, just as certain students will understand certain topics better than other topics. This gave me more of an idea of what the student is like and how that is affecting their grades in school, which is how performance is measured. There were also questions on the survey asking if they had a tutor or went to any tutoring. This gave me more of an understanding of if they needed extra help besides what was available to them within the school to understand what was going on. If a student missed a day, that is more understandable if they went to the tutoring session to make up the time they missed, but that is different than students who went to tutoring because they need more time to understand the concept. The survey also had questions like if they came to retake the exam after getting below 70% to help increase their grade to know what they were doing to try and help increase their grade when it comes to exam time.

Another tool I used was observations and interviews with teachers. I took all my observation notes and interviews down in a scientific journal with all data in the journal. The reason for this was to see what they were doing in their classes that might be different from the other classes. I got an idea of how the different levels are being taught amongst the teachers and an idea of what was going on within the classroom that was affecting their data.

The last type of tool I used was tests, which is the quantitative data. To know how the students did within each test, and what grades they got, it helped me know how they did overall with the unit of physics, and specifically how they did with the mathematics heavy units. With knowing what grades, they got a breakdown to look at it all and compare it with their math grade as well as their final grade. I used this through Google

Docs, so the teachers had access to be able to insert the data for their test grades into it, and so I would be able to look at the data and compare it. This gave me a better idea and made it easier to access instead of going through all the different teachers to be able to get my data.

In Appendix H, there is a timeline that shows the entire year of how the data was collected. As the school was on an accelerated block schedule, the school year "began" twice, where the students started the class either on the first day of school, August 28, 2017, or when the new semester began January 22, 2018. From there it goes to show when each of the data was administered and collected, about how long each unit was before the next test, as well as when important data was taken for each of the other Appendices.

Data Analysis

I analyzed the data by looking at what their math grade was and compared it to each of their test grades within physics by looking at the math component of the grade. When looking between the concepts, I saw what students were focusing more on, how to do their math or understand the concepts. I also looked at if they were getting extra help outside of class to be able to do better within the course or if just the knowledge and sitting in class was serving them enough. If students were going to a math or physics tutor, then students are doing more to help improve their grades and how they do on the test. If they only go every once in a while, then it was just that topic. If they have one the entire time, then the data isn't helpful as students are having many interventions and not sure if the student is really getting what the teacher is saying and can do it themselves or getting the extra help because the ability isn't fully there.

In the end, I looked at the different math courses, what grades they got within the course, and made the best recommendations based on the evidence for what is the best math course needed prior or concurrently with the level of physics class they are in by looking at all the averages of the physics tests.

Summary

During the research, data was collected using the mixed methods research approach known as Sequential Explanatory, one of Creswell's Mixed Methods Strategies (Creswell, 2003). The research was conducted in a 3200-student suburban southwestern state school within a district that reaches 13 different suburban cities. The research was taken for students taking Physics courses, including all the different levels of physics like Physics, Pre-AP Physics, and AP Physics 1. From there, data was collected and looked at from all students participating.

Within the data, I looked at students' previous mathematics grade that they received before taking physics, as well as taking in what they think about mathematics and science, as that can affect how they are going to do within the class. From there, I observed teachers on how they were teaching their students, interviewing what they are doing within each unit, as well as taking students' test scores, and surveys on how they think they did, and what things they did to help prepare them for the test. This gave me more of an understanding of what they, the students, were thinking about what they did on the test. At the completion of the course, there will be a final survey that is similar to the first survey they will have completed, which included additional questions for the students to answer. While this data is being taken, I interpreted the data, and in the end, drew a conclusion on what I have seen within the data.

The next chapter will go into looking at the data collected from students and staff. It will look at and talk about what was seen from the students' mindsets, teachers' mindsets, and overall how the students did in the class compared to their average mathematics grade that they had before taking physics.

CHAPTER FOUR

Results

Introduction

Does the mathematics level affect student success in high school physics? As we have read the research in Chapter 2, if physics is last in the sequence of science courses taken in high school, there is a consensus in the literature that mathematics be a requirement needed for students taking physics. Physics is often seen as a tough course that students who want to go to college take to help prepare them when it is taken in the last of the sequence order. It was the course that students who had taken higher-level mathematics courses took to be able to challenge themselves more. As more students are planning on going to college these days, more students are signing up to take physics without the proper background courses needed to be successful to their fullest potential. They are taking the class knowing the colleges want to see the course on their transcript, but not taking the higher-level mathematics courses with it.

Throughout this chapter, I talk about what my fellow colleagues talked to me about while observing their students who had taken physics. They spoke in general about their background, expertise, and things they notice about students. This is important to see as they are the ones teaching and evaluating the students. You will also see student's points of view on mathematics, and science courses through a survey to see how the students think about it before beginning the course. They were even asked what they had heard about physics to see what their views of the course are before it begins.

It also talks about trends seen based off of students' previous mathematics course they had signed up for and the grades received in those courses, and the trends seen before the courses began broken down by the level of physics the students were taking: Physics, PreAP Physics, or AP Physics. This is important to see as we see how all the students are broken up and what the majority of students are taking certain courses, and how that affects the teaching, or affecting the grading based on who is teaching it and at what level. The students were also surveyed after every test. Within the survey students gave teachers insight on what they thought about their learning, how their test grade compared to their expectations in what they did to prepare, and what could have affected their grade during that unit. I, along with the teacher colleagues participating in the study, looked at what the students thought about how they did, what was seen as results, and what students thought about each unit. This is important to be able to get an idea of what the kids are thinking and to have more of an idea of what they are going through and struggling with or have an insight to. We also kept track of the students' test grade data and looked at it broken down by which level of physics they were taking. This is important as this gives us their average and helps determine how it matches with their mathematics grade to see how much of a correlation there is when looking at it.

Colleague Interviews

Before starting with survey data with students for the year, I gathered some background information through individual interviews with five of my fellow colleagues.

There were six teachers, including myself, who ended up teaching Physics in our department, which contains eighteen science teachers in total. When interviewing the teachers, of the six who were teaching physics this year, only one had a physics degree. The other teachers had degrees in, Exercise Science, Genetics, Chemistry, Sociology, and Chemical Engineering. When asked about how many physics courses they had taken in college, two of the teachers had not taken any physics courses, one had taken a physics course for health science majors, two had taken two physics courses, and one had taken more than two physics courses. In the Southwestern state where this data was being collected, the state does not require a content major in order to be licensed to teach physics. The state requires that there be 30 credit hours of any science in order to get a composite science license that then allows the teacher to teach any of the science courses. This set of interview questions again goes to support the theme that “most high school physics courses are not and have always been taught by teachers who were never specifically prepared for that job, and how have not had the requisite preparation recommended by physics educators” (Meltzer & Otero, 2014).

Although there are six teachers teaching physics, each teacher teaches a different level, which affects the number of teachers teaching each level, as not all teachers are teaching entirely physics. One teacher had 4 sections of regular physics for the year and integrated physics and chemistry; one had 2 sections of regular physics for the year and aquatic science; one teacher had 2 sections of regular physics for the year and astronomy; one teacher had 2 sections of PreAP physics for the year and chemistry; one teacher had 4 sections of AP physics and computer science, and one teacher had 3 sections of PreAP physics, 2 sections of AP physics, and a section of study hall.

I had asked the teachers if they think there should be a math prerequisite before taking physics. The teacher had all said in each of their own interviews that they believed that there should be. Most went on to say that they believed that all students should have taken Algebra 2 before taking physics. The teachers believed that it helps the students as the teachers spend more time teaching mathematics than being able to teach more physics concepts. Because current standards require the use of mathematical skills to help prove certain physics concepts, many of these teachers say they spend much of their time teaching these skills instead of being able to teach more concepts or to even allow more time to get more in-depth with certain concepts they are covering. They said that they want them to know these mathematical concepts to then help the students see how it works with physics when they don't seem to understand when they first explain the concept to them. Many had said that based on past experience, many of their students who had completed Algebra 2 were able to understand the content they were teaching when other students seemed confused based on using their mathematical knowledge and the relationship they saw in the equations and between the variables.

When asked "What are some issues you have while teaching?", many teachers talked about how much time they spend on teaching mathematical skills, and how they believe their students just memorize steps instead of understanding the process. They said they believed that many of their students start to memorize a process instead of understanding what the question is asking, or using the problem-solving skills that they have learned or learn through this class. This observation of the teachers is based on past student behavior where students experience a similar yet different question they've had before and treat it as if it was the old question instead of reading the problem to answer it correctly. Many say they have this problem and end up walking the students through the steps repeatedly. The teachers talked about how they see that students are missing fundamental mathematical skills that are needed for the course.

As many of the students are missing these mathematical skills, the teachers end up spending time teaching these skills. None of the teachers have a mathematics teaching license or have had any training in how to teach mathematics. As the teachers do not know how to teach mathematics, many teachers teach certain mathematical skills they need the students to know based on the way they have been taught from their teachers growing up. When this is done, many students who do not recognize this way or do not seem to understand this way get confused and still have this lingering problem when encountering new physics problems. This at times can make it unsure if the student does not understand the concept of the physics behind the problem or the mathematics behind the problem is what many of the teachers reflected on and said. This is one reason why the teachers said that they wanted a prerequisite for physics so that they do not have to teach the mathematical skills to students for sometimes the first time when they do not have the training to teach mathematics.

When teachers were asked "what was one thing they wished they had more of", they tackled how they wished there were more lab equipment and more time to do labs. There is one class set of lab equipment that is shared amongst the six teachers who teach physics. Some years the number of teachers teaching physics can increase, and sometimes decrease, affecting how teachers can properly share equipment. This makes it hard for them to do a lot of labs as a result of needing to share the equipment, and a limited amount of days to get through all the content they need to teach. Because of the lack of equipment, and the lack of funding to get more equipment, many teachers end up not doing as many labs as they wish they could do. This has been an issue with many teachers and has been talked about for years within physics education history. Physics education researchers believe that teachers with a lack of physics experience can teach students more properly if teaching students physics through inquiry-based labs (Otero & Meltzer, 2016). If teachers do not have the proper background knowledge to teach physics, then they can have the students discover the concept they are learning themselves and teach the concepts from there. Yet, how is this possible if there is a lack of lab equipment and a lack of funding for teachers to get that equipment? This makes it harder for physics teachers to teach without giving the students the opportunity to investigate on their own when there is a lack of resources. It makes it extremely difficult as teachers have to find other ways to be able to teach the content, which may use mathematics if they do not have enough resources to give students labs to explore. This also does not help the students who lack the mathematical skills to even see the relationships between the variables they are looking at to see how the physics and the mathematics connect when labs are not able to be used.

After talking about the lack of equipment to then make a lack of labs, I asked what a typical unit for the teachers looks like. Many have their unit spread out over a certain amount of days, and the days vary depending on the difficulty of the content they are teaching during that time. All teachers included lecture times, where students learn the content for the unit, usually always on the first day of the unit, work time for students to work on physics worksheets or their homework, and lab days. All teachers had all of their units include at least two lab days, which include the kids working in groups to collect data from a lab. Some units have more labs, depending on equipment availability.

The teachers were different in how they split students into groups for labs. Some teachers had the students get into groups randomly based on how they entered the room or random group generators, and others allowed their students to choose their lab groups. All teachers had their students have questions about the lab that they needed to answer. All the teachers' typical lab time took the whole period where students gathered data, answered analysis questions, and usually created some graphs to show the relationship between the variables they were investigating. The majority of their students always completed the entire lab by the end of the class period.

When asking the teachers do they think students' mathematics level affects their success in their physics class, many of the teachers believed it does. As many of the teachers teaching physics had background knowledge in areas other than physics, this supports the theme in the literature review that many high school physics teachers do not have the requisite preparation recommended by physics educators. This results in teachers relying on the mathematics background that students have to teach physics. Many of the teachers are finding that the students are lacking many of the mathematical skills they need to have to be successful in physics. They feel that students need to have a certain mathematics course before taking their physics class so that they are able to teach the students more, and so the students are able to understand the teacher better. They feel that this would allow more time to do more labs as the teachers feel they spend more time than necessary teaching the mathematical skills that students seem to be lacking.

Based on the colleague interviews, it seems that many of the teachers do not have a certain degree and background knowledge compared to other states or even what physics educators request that teachers have to teach physics. This then allows many of the teachers to rely on the student's mathematical skills to help learn the concepts as many of the students understand mathematical relationships as they learned them in previous classes. Yet many of the teachers also find that they do not have the background knowledge or training to teach students the mathematical skills that they need their students to have in their class. This means that they end up teaching many of these mathematical skills themselves based on how they learned, instead of how students have learned or seen it. This can create lots of confusion and other problems as students and teachers continue through the curriculum. All of the teachers include labs within their lesson plans, yet do not do as many as they’d like due to time constraints and having to share equipment with other teachers. This does not allow another way of learning for students to help learn and solidify concepts students are learning. Lastly, all the teachers believe that a certain mathematics class does affect success in their class as many of the students are more successful when having had higher-level mathematics, making teachers believe they have a high level of understanding those certain mathematical skills.

Demographics

All data that is looked at is from the students whose consent forms were turned and had indicated that they agreed for their data to be used. The groups of how the data was taken were broken down into the different physics levels and then also looked at for an overall consensus as well as seen in Table 1. This shows how many sections of each different physics class was available, how many teachers taught the certain course, the number of sections offered, and the total number of students in the course as well as how many students participated in the study. As one can see, there was 50% participation of the students in the Regular Physics course, 71% participation of the students in the PreAP Physics course, and 44% participation of the students in the AP Physics course. There was an overall 51% participation rate for all students taking physics in this school year.

Table 1

Total Numbers

Different Physics Courses	Number of students information taken for study	Number of students in the Course	Number of Total Sections for Course Offered	Number of Different Teachers Teaching the Courses
Regular Physics	81	192	7	3
PreAP Physics	91	128	5	2
AP Physics	56	127	6	2
Total	228	447		

The entry-level of introductory physics class, Regular Physics, had a total number of seven sections with 192 students taught by three different teachers. A total of 81 students agreed to participate in the study. Within this group there was 60.49% were female, and 91.36% were juniors. The mid-level of introductory physics class, PreAP Physics, had a total of five sections with 128 students taught by two different teachers. A total of 91 students agreed to participate in the study. Within this group, there were 48.35% of the students were female, and 93.41% of the students were juniors. The advanced level of introductory physics class, AP Physics, had a total of 6 sections with a total number of 127 students in the course that were taught by two different teachers. A total of 56 students agreed to participate in the study. Within this group, 37.50% of the students were female, and 89.29% of the students were juniors.

Table 2

Grade Level Break Down of Participants

Different Physics Levels	9th	10th	11th	12th
Regular Physics	0	4	74	2
	0.00%	4.94%	91.36%	2.47%
PreAP Physics	0	3	85	3
	0.00%	3.30%	93.41%	3.30%
AP Physics	0	4	50	2
	0.00%	7.14%	89.29%	3.57%
Total	**0**	**11**	**209**	**7**
	0.00%	4.82%	91.67%	3.07%

When looking at the overall grade breakdown between the sections in Table 2, as well as the total number, it is interesting to see that the percentage of students between the different grades seems to be consistent no matter what level the students are taking the physics course. It seems that the majority of students taking physics are juniors, which fits with the model of "physics last" to come after biology and chemistry.

Table 3

Gender Break Down of Participants

Different Physics Levels	Male	Female
Regular Physics	32	49
	39.51%	60.49%
PreAP Physics	47	44
	51.65%	48.35%
AP Physics	35	21
	62.50%	37.50%
Total	114	114
	50.00%	50.00%

When looking at the gender breakdown of the participants in Table 3, it is interesting to see that my participants are 50% female and 50%, male. However, when looking at the gender breakdown between each section, I saw that only 37.50% of students were female taking AP Physics, while 60.49% of students were female taking Regular Physics. This was interesting to see that there are just as many female students taking physics as there is male, however, they seem to be taking more of the entry-level physics course compared to the advanced-level physics course.

First Day Survey

The first data that was collected from the students consisted of a survey that was taken on the first day of school. All the teachers did this with all of their students, but only data was collected from those who had returned their agreement to participate forms and were looked at on a later date. The questions in the survey were composed of the questions being used in the study, as well as other questions that the teachers used to help start out their year. Data from the survey was reviewed by both myself and the teachers of the courses. The data captured a look at the students' mindsets and conceptions of math, science, and physics before the course started.

When the first-day survey was given out, the questions were composed in a way for short answer responses from the students. This way one was able to see some reasoning behind their answers if the student chose to explain further. It also allowed for more expressions to see as some students chose to say they "liked the subject, but it was hard for them", giving some thoughts that the student would try hard in the class, even if it difficult for them compared to students who said they "did not like the course", giving the idea that they might not try hard when given harder problems, which could affect the data. After looking at the participants' responses initially, I categorized them into certain categories based on what the majority of the students were saying to then analyze the data.

Table 4				
What Do You Think About Math?				
Different Physics Levels	Dislike	Okay	Like	Inconclusive
Regular Physics	28	21	26	6
	34.57%	25.93%	32.10%	7.41%
PreAP Physics	29	28	27	7
	31.87%	30.77%	29.67%	7.69%
AP Physics	14	12	26	4
	25.00%	21.43%	46.43%	7.14%
Total	**71**	**61**	**79**	**17**
	31.14%	26.75%	34.65%	7.46%

In Table 4, students were asked the question, “What do you think about math?”. Based on their answers, they were categorized into the categories dislike, okay, like, and inconclusive, as those answers did not fit any of the other categories. When looking at the data, an overall 31% of students said that they disliked mathematics or thought it was hard. Physics educators have said that students who dislike mathematics tend to stay away from Physics, which makes sense that the percentage is low as many of these students might have taken other science courses offered and stayed away from Physics as it is a more "challenging course" according to sources. It was surprising to see that 25% of the AP Physics students thought this as well, as that course uses more mathematical skills than the other two courses. I thought this was surprising because these students are on the more advanced track with sciences, and usually in the advanced mathematics courses as well, yet they are saying they dislike mathematics or think that it is hard.

The students that fell into the okay category said that "mathematics was hard, but they liked it". About 26% of Regular Physics students, 31% of PreAP Physics students, and 21% of AP Physics students fell into this category. This told me that these students were more likely to work on the content even when they found it to be hard as they have more of a growth mindset and believe that they can change, or enjoy the content enough to continue to work on things that do not come as easily to them.

Table 5

What Do You Think about Science?

Different Physics Levels	Dislike	Okay	Like	Inconclusive
Regular Physics	17	26	27	10
	20.99%	32.10%	33.33%	12.35%
PreAP Physics	4	30	47	10
	4.40%	32.97%	51.65%	10.99%
AP Physics	7	5	29	5
	12.50%	8.93%	51.79%	8.93%
Total	**28**	**61**	**103**	**25**
	12.28%	26.75%	45.18%	10.96%

In Table 5, students were asked the question, "What do you think about science?". Based on their answers, they were categorized into the categories dislike, okay, like, and inconclusive, as those answers did not fit any of the other categories. When looking at this data, an overall 12% of students disliked science courses. There were 21% of Regular Physics students, 4% of PreAP Physics students, and 12.5% of AP Physics students. What this tells me is that the students who are taking Physics are students who enjoy and like science or find it easy. I believe that the majority of the students signing up to take Physics are the students who do well in science, and love science as well as are up for the challenge. In the history of physics education, it has always been the course for advanced students who wanted to go to college. It seems that this percentage from the survey is implying that it is the top students who are enjoying science and planning on college with some sort of science or medical focus, which is why they are taking the course. Now the survey did not ask these students that question, but it is a possibility as there are many other choices of science courses for students, and physics is not required for students to graduate if they've taken Chemistry. This then leads me to believe that would be the reason why the students are signing up for the course.

What is interesting about this data is the fact that PreAP Physics students have fewer students than dislike science compared to AP Physics students. I find this interesting because I would have figured that AP Physics students would have the lower percentage of students who disliked science as the course is a difficult subject and often only pursued by students who like science classes. It makes me wonder if students are signing up more for the AP Physics course to then help with their GPA more than wanting to learn the content within the course. The reason I bring this up is that the mindset for the students change to not be as much as interested and wanting to learn the content but instead shift to how can I get the best grade. The focus shifts from learning to figuring out how to get an A, which can mean some learning is lost in the process. No question was asked about why they chose the class they did, which could have provided more insight into this.

Table 6

Do You Need Math Skills in Science?

Different Physics Levels	Yes	No
Regular Physics	58	23
	71.60%	28.40%
PreAP Physics	82	9
	90.11%	9.89%
AP Physics	47	9
	83.93%	16.07%
Total	**187**	**41**
	82.02%	17.98%

In Table 6, students were asked the question “do if you need math skills in science?” to see if students knew there was a correlation between the two. This gives insight on how many students are open to the idea they will be using mathematical skills in the class, and how many do not think there should be. An overall 82% of students answered that math skills were needed in science courses. The level of physics that had the lowest amount of students who answered yes to the question were students in the regular physics class, which is the class with the least amount of mathematical skills held within the class. This shows me that many of the students know there is a connection between the two variables, which gives hope that many of the students had an idea of what physics entailed before coming into the course.

Table 7

What Have You Heard About Physics?

Different Physics Levels	Hard	Math	Hard + Math	Easy/Fun	Inconclusive
Regular Physics	30	17	2	5	27
	37.04%	20.99%	2.47%	6.17%	33.33%
PreAP Physics	33	16	9	4	29
	36.26%	17.58%	9.89%	4.40%	31.87%
AP Physics	23	15	5	3	10
	41.07%	26.79%	8.93%	5.36%	17.86%
Total	**86**	**48**	**16**	**12**	**66**
	37.72%	21.05%	7.02%	5.26%	28.95%

In Table 7, students were asked “what have you heard about physics?” to get an idea of what many of the students had heard to know what exactly they were thinking. The question was an open response, and answers were categorized into implied they heard the class was hard, had math in it, was hard and had math in it, it was easy and fun, or something that did not entail any of that. When looking at the data, I saw that only 5% of students in all levels of physics had heard that the course was easy or fun. The majority of the students had heard from previous students that the course was hard, had math, or both. 66% of students overall had heard that. The percentage amongst each section stayed around the same, except for regular physics, where only 2% had said that it was hard and had math. This was talked about in the literature review, which is why many students had steered away, or already have a distaste for Physics as many come in with this mindset based on previous students’ comments. It draws some curiosity about how many students will think that way about the course at the end as well as if they will like the class and accept the challenge, or if they will dislike the course at the end. What this tells me is that many students come in with this knowledge, which can discourage some students from really trying when they encounter difficulties, while others might know that they will be working hard in this course. It is not really known about as the question was not directly asked, but this data did help get a better understanding to see at the end what students really thought about the course.

Table 8		
Have You Hired a Science Tutor		
Different Physics Levels	Yes	No
Regular Physics	6	75
	7.41%	92.59%
PreAP Physics	3	88
	3.30%	96.70%
AP Physics	0	56
	0.00%	100.00%
Total	**9**	**219**
	3.95%	96.05%

Table 9		
Have You Hired a Math Tutor		
Different Physics Levels	Yes	No
Regular Physics	17	64
	20.99%	79.01%
PreAP Physics	24	67
	26.37%	73.63%
AP Physics	12	44

	21.43%	78.57%
Total	**53**	**175**
	23.25%	76.75%

In Tables 8 and 9, students were asked if they had hired a math or science tutor in the past to get an idea of how many students had hired someone in the past to know the baseline when students are asked about it in the coming semester. This was done to get an idea of how many parents insist on their students having a tutor for the class and already go to that option first. What was interesting about this data is that only 4% of students overall hired a science tutor, as seen in Table 8. None of the AP Physics students hired a science tutor in the past, and the majority were regular physics students. This tells me that many students do not go to seek tutoring in the sciences, which again tells me that the majority of the students taking physics are students who enjoy the sciences. However, in Table 9, 21% of AP Physics students and Regular Physics students, and 26% of PreAP Physics students had hired a math tutor. This tells me that either there is a problem with certain math teachers students are learning from to hire someone, or this is the students who dislike math already and usually seek outside help to do well in the course. I think I was most surprised to see AP Physics students with this percentage because again, students are on the more advanced track with sciences, and usually in the advanced mathematics courses as well. To see that about one fifth of the students are hiring a mathematics tutor and they are usually taking the more advanced mathematics courses raises some concern and questioning on why they signed up to take the course.

Mathematics Course Observations

After going through the first day surveys, I went through all the students who agreed to be a part of the study and looked at their previous mathematics course and grade before taking Physics, something I always do once I get my roster. Based on each physics course, I then proceeded to categorize the students into which of the following mathematical courses they took and created pie graphs to look at it. The courses on the side key are listed from Algebra 1 up to the highest mathematics course taken by any student(s) within the course, this varies based on the physics course as some students took physics, and other students did not take physics. Something to keep in mind when looking at the data for any class that there will be PreAP listed for some of the mathematics courses. These courses are like an “honors” class where it shows they cover the same content as the other course, but oftentimes at a much faster pace as well as sometimes more material compared to the regular course.

Another thing to keep in mind when looking at the data is remembering the order of mathematical courses students take, and when they usually take it. Based on what they take in middle school, the time in which the math path is chosen, it can determine when students learn certain classes. If a student is on the “faster path”, they are more likely to take Geometry in 9th grade, Algebra 2 in 10th grade, PreCalculus in 11th grade, and Calculus in 12th grade, which is only offered as AP Calculus in the current school. This does not include if a student chose to take the PreAP version of these courses. If a student is on the “normal path”, they are more likely to take Algebra 1 in 9th grade, Geometry in 10th grade, Algebra 2 in 11th grade, and PreCalculus in 12th grade. Both of these are also if a student chooses to take a mathematics class all four years in high school and does not choose to take Statistics, which is often taken after a student completes Algebra 2. Most students continue to do this order, even though there are no prerequisites for math either because most people know the order for math as they took it in this order when growing up.

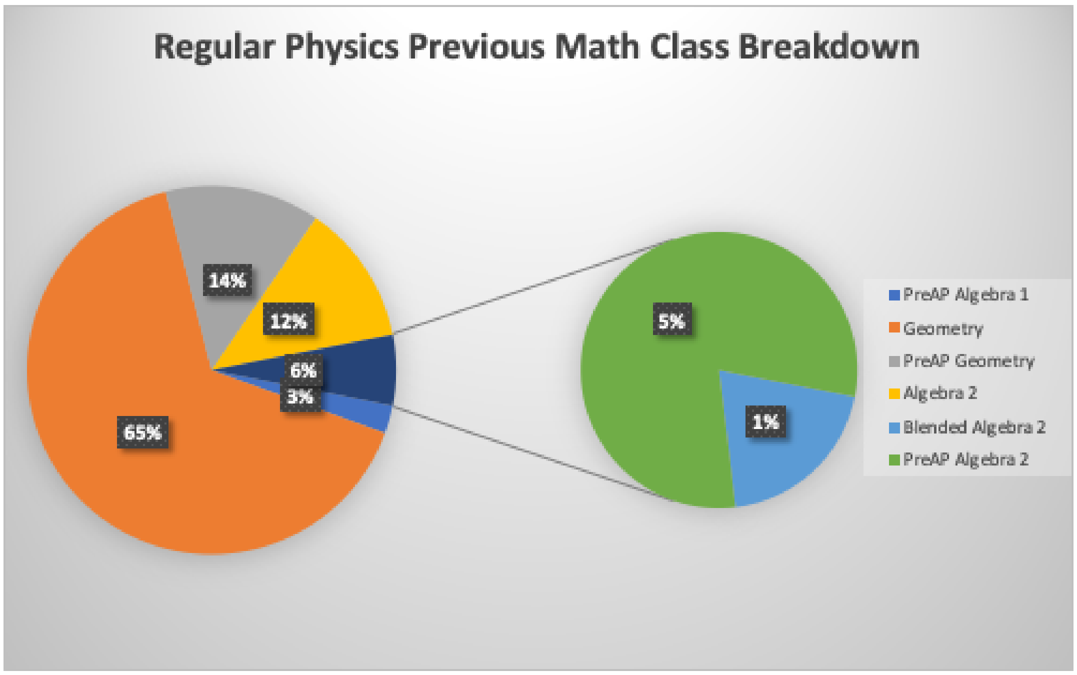

Figure 1 - Regular Physics Previous Math Class Breakdown. This figure illustrates the different math classes students previously took before physics.

When looking at Figure 1, the courses are listed from PreAP Algebra 1 to the highest course taken by students in this course PreAP Algebra 2. It shows the percentage of students who took those certain classes before taking physics. Students were not asked if they were taking a certain mathematics course at the same time as taking physics as the students are on an accelerated block, and many may not be taking math at the same time. When looking at the data, seeing that 3% of students had taken PreAP Algebra 1 before taking this class made sense as 4.94% of the students were 10th graders as many 9th graders take either Geometry or Algebra 1, either PreAP or regular. These students could have been taking Geometry at the same time as taking Physics, but as stated earlier, was not asked that question.

When looking at Figure 1, you can see that 79% of students had Geometry (regular and PreAP) before taking Physics, 65% regular, 14% PreAP. This goes to tell me that many of these students are in the “normal path” of their mathematics courses as 91% of the students in regular physics are juniors. This is interesting as many schools recommend that students have Algebra 2 before taking Physics, yet there were a lot of students not in this survey. These students could have been taking Algebra 2 at the same time or sometime within the year, but that is hard to know since the students are on an accelerated block and do not get to choose when they have their math and science courses. As most skills learned in Algebra 2 end up being skills used in Physics, it was interesting to see that many students were signing up for the class despite the recommendation to have Algebra 2 before taking the class. Based on this, it made more sense on why many teachers talked about how they have to teach more of the mathematical skills in class, and have less time on the physics concepts as many of their students have seen introductory algebra skills, and geometric skills before class, but not the more advanced skills that is used more in physics. This then causes the teachers to end up spending more time on a certain subject trying to teach the students the math and then the content, and oftentimes not covering the content with as much depth as a teacher wants in other units when time is running out.

My worry about the current curriculum, when teachers decide to slow down to help students with mathematical skills, is that some students are becoming bored easily. The reason for this worry is because 22% of the students have taken PreAP mathematics courses. This means the students learn at a faster pace and often are grasping the mathematics more than their fellow classmates.

The last thing Figure 1 showed me that really makes me wonder was that 2.47% of students taking regular physics are seniors, yet 0% of those students took PreCalc. This tells me that the senior students are most likely on the "normal path" for their mathematics route as they would be taking PreCalc their senior year if they chose to do so, and had taken Algebra 2 their junior year before taking Physics. Since 18% of students had taken Algebra 2 in some form before taking Physics, this makes more sense as there is a mixture of students who would have taken Algebra 2 their junior year before the course, i.e. they had Algebra 2 in the fall, and physics in the spring, or their sophomore year as they were on the math "faster path".

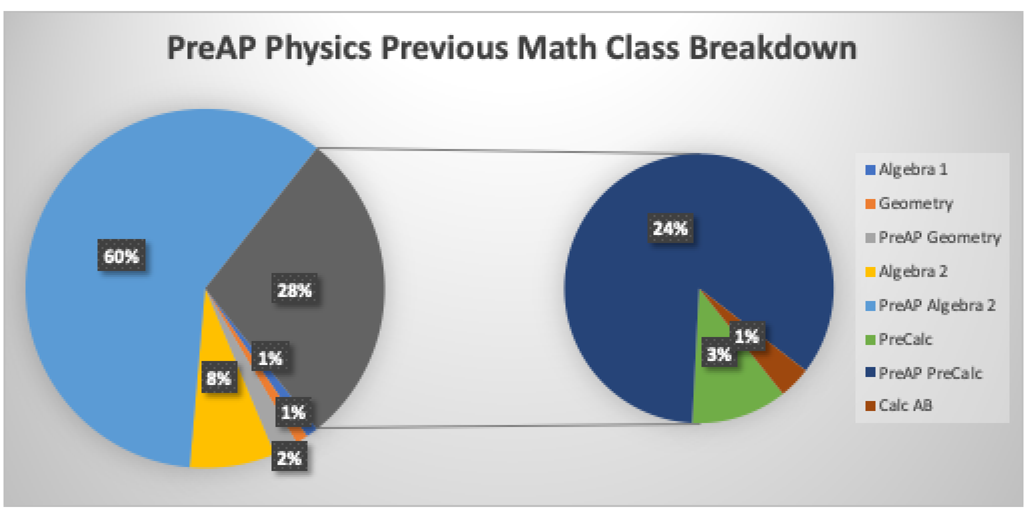

Figure 2 - PreAP Physics Previous Math Class Breakdown. This figure illustrates the different math classes students previously took before physics.

When looking at Figure 2, the courses are listed from Algebra 1 to the highest course taken by students in this course Calc AB, which is only offered as an AP course. It shows the percentage of students who took those certain classes before taking physics. Students were not asked if they were taking a certain mathematics course at the same time as taking physics as the students are on an accelerated block, and many may not be taking math at the same time. When looking at the figure, you can see that 1% of students had taken Algebra 1, and 3% of students had taken Geometry (regular or PreAP). This makes sense as about 3.3% of the students signed up for PreAP Physics are 10th graders. 68% of the students had taken Algebra 2 (regular or PreAP) before taking PreAP Physics, which fits as many of these students are juniors and had either had just taken Algebra 2 the previous year or that current semester based on which math path they had taken, as talked about earlier. This tells me that I have students on the two different math paths not only by how many students took Algebra 2, but also by how many took the upper level courses as 28% had taken PreCalc or higher.

The other thing the data shows me is that 86% of these students are PreAP/AP math students by having taken PreAP math courses or AP Calculus. This tells me that these students are used to learning their mathematical skills at a faster pace, which matches the fact that they signed up for PreAP Physics as that is also taught at a faster pace than regular physics. This makes sense as when a student takes an advanced math course, they often take an advanced science course as talked about in the literature review. The skills they learned and the rate at which they learn their mathematics at is the same rate at which they will learn their physics content with not as much instruction spent on going over mathematical skills as many of them had taken the course before that and would most likely be spent more on reviewing than teaching those skills.

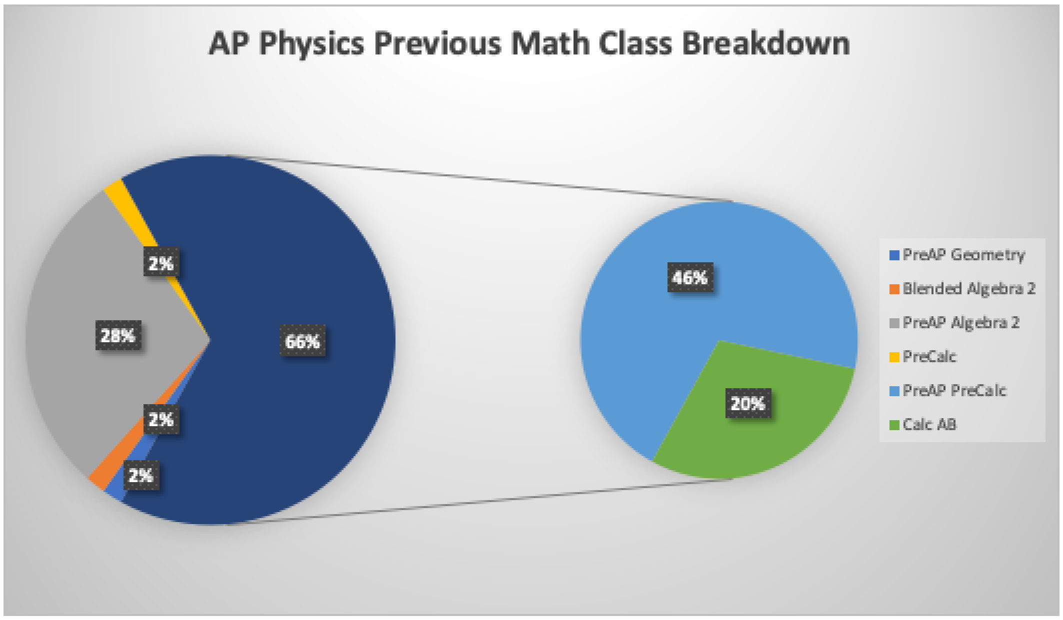

Figure 3 AP Physics Previous Math Class Breakdown. This figure illustrates the different math classes students previously took before physics.

When looking at Figure 3, the courses are listed from PreAP Geometry to the highest course taken by students in this course Calc AB, which is only offered as an AP course. It shows the percentage of students who took those certain classes before taking physics. Students were not asked if they were taking a certain mathematics course at the same time as taking physics as the students are on an accelerated block, and many may not be taking math at the same time. When looking at Figure 3, there were many things that stood out to me. The first was that 2% of students had taken Geometry, while 7% of the students were 10th graders. This tells me that the students are more on the "faster path" for math courses as Geometry would have been taken before the student came to

Physics if their math was taken the previous year. I also saw that 68% of the students had taken PreCalc or higher, which tells me that the majority of the students taking the AP Physics course are more likely to be on the "faster path" for math courses. The reason I draw this conclusion is because only 3.57% of the students are 12th graders, and yet there are still 20% of students who had taken Calculus AB already before taking Physics, which is usually a 12th grade course. This tells me that either students were taking Geometry back when they were in 8th grade, or many of these students "doubled up" on math courses, meaning they took two math courses in one year to be able to complete this. This is able to happen in the school as what is traditionally done in one whole school year is complete in half of the year, allowing students to "double up" on math courses. The reason why I draw this conclusion is that 48% of the students had PreCalc, which is often a junior or senior level course, and 20% had Calculus, which is a senior level course. The majority of the students taking AP Physics are juniors, so the conclusion is made based on this.

The other thing the figure shows me is that 96% of the students are PreAP math students. What this tells me is that the majority of the students are used to the fast pace of the math courses and are used to the academic rigor. When looking at the 28% of the students who had taken PreAP Algebra 2 before taking AP Physics, most of the students, with a few exceptions, were students with A's or high B's in their PreAP Algebra 2 class. This goes to tell me that they are students near the top of their class who are college bound and wanting to push themselves as Physics is the type of advanced course that many colleges want to see, as talked about in the literature review. This means that many of these students are taking the courses to be able to try and receive the skills of problem solving by taking the more advanced level courses, including AP Physics instead of Regular Physics or PreAP Physics.

As talked about in the literature review, the higher the student's mathematical level, the more likely they are to take Physics. This matches with students who signed up for AP Physics, yet not with PreAP Physics or Regular Physics. Between all the different levels of physics, it can be seen that the students have many different backgrounds in mathematics, not even including where the grades stand to show the level of mastery. This definitely pushes to either have the curriculum be adjusted to match the needs of the students, more to the level all students are at, or there needs to be a requirement in place based off of the current majority of student mathematics level to allow for a teacher to be able to figure out where the students are at. It allows the students to know what the expectations are before coming to that class, and might give some of them the knowledge that it does include mathematics in it. Since the standards are written and then interpreted by a group of physics teachers, they often envision them being taught with students having a certain level of mathematical knowledge, ie Geometry, or Algebra 2 before taking the course. Since no requirement is in place, it makes it harder for the teachers who read the standards to know exactly what the district wants when the teachers don't know what mathematics level was in mind when writing those standards. This causes many teachers to stress over what should be taught, what should be shortened on with teaching to be sure that all the content is covered by the teachers.

If a requirement was put into place based off of where majority of students are currently with their mathematical ability when signing up for the courses, it could allow teachers to plan their content appropriately, knowing that they are teaching to the majority of the students without having to wait until schedules are made, look at their schedules then make those decisions at the last minute and constantly adjust plans throughout the year. It would also allow for teachers to see if they really are teaching more mathematics or to see if they just believe they are as their plans constantly get adjusted as that seems to be the one issue many students have that they seem to work on the most. Teachers would also be able to really figure out what they need to focus on in their teaching to improve learning either through making sure they understand a physics content a little more in-depth than they previously did, or a different way to teach a topic to be able to reach more students. By knowing where the groundwork of where everyone is at would be able to help teachers know their starting point, instead of guessing their starting point and either having it be too easy, or too difficult for students to then constantly change based on the year as one year could have students that had more PreCalc in a class versus the next year has more Geometry in a class. It would really help the teachers know where to begin.

Student Surveys Throughout the Year

Not only were the students monitored on each of their tests, but they were also given surveys to complete at the end of each unit. It was interesting to see that throughout each of the tests, they were not satisfied with the grade they got as they didn't think it reflected on what they really knew. As the school year went on, students started to actually start agreeing with their grade, that it really did show what they knew. When talking to students about why they thought they deserved a higher grade, or why they didn't think it reflected their true knowledge accurately, they said it was because they studied more than they had in any other class before taking this class. They constantly commented that they did a lot of studying, but when asked what kind of studying they did, it was commented that they just did most of the worksheets given to them, which are more mathematical, but did not go over their notes. This was telling me that students believe that how much time they put into their studying and learning should reflect on what grade they should receive. They believe that if they spend more time on something, even just doing tedious work, they should be getting a better grade, which is not the case. They could just be going through the motions, and not really investing and testing themselves when studying the material. They are not truly studying, but instead going through motions of what they think is studying.

As the year went on, I received some anecdotal data from the students about what they were doing to study. More students started saying they started going over their notes as well as doing the homework to prepare for their tests. When asked again in the survey, the students that had started putting that they went through their notes before the test believed that their grade was correctly showing their knowledge as they finally learned to stop going through the motions and to actually study. When I followed up the survey with some questions, I was told by many of them that they had started turning off distractions that they had around them to be able to focus more on studying. Now although many of the students made the comment that they believed that they get enough work as it is, the students who truly started studying thought they had just enough work to make sure they truly mastered the knowledge and found it worth their time to be able to get the grade they wanted.

This told me that many of the students did not know how to study and that most were just doing what they thought would cover all of what was going on the test, instead of looking at all their resources. I was not expecting to see this in the data, as I did not read about students not knowing how to study or that correlation. It was interesting to see, however, that many of the students did complain about not having enough time, or they thought one worksheet was “enough” at the beginning as the students believe they have too much homework, which was seen in the literature review. Yet these students slowly learned that the homework was not busy work, but another way for them to learn the material and be able to master it if done the correct way and a better way of thinking.

I, as well as other teachers, ended up teaching more study skills to students than had previously intended as we had seen that students did not know how to study or were never taught how to study. We also taught them the value of their homework as something to invest in instead of being busywork. As we did this, we saw that many of them started to see the correlation with their studying and their test scores became more of one. Not only did I see more of that, but I also saw growth and confidence in the students who were unsure about the class as they put more into it. This was not all of the students, but the ones who did end up with a higher grade based on the patterns I was seeing. This was also true for students who did not put in much work to try and get a better grade or did not do any of the classwork given to them.

Through all of the surveys for students throughout the school year, we were able to see that more students learned what studying was and started to see the value in true studying and the grade that they received. They started to agree that their grade was starting to correlate with their actual knowledge of the content. Students started to feel more confident, and some students put in more work to be able to pull off higher grades than the patterns we were seeing. This was very interesting to see to be able to explain the discrepancies in the patterns that were seen within the data.

Final Average Grade

As the school year went on, I kept data on students and their grades for each unit. At the end of the school year, I took the average of all their test grades and looked at it, as well as compared it to the mathematics grade they had from their previous math course to see if there was any correlation or pattern. To keep the student's confidentiality, they were assigned a code to be able to tell the difference between them. If their number starts with an A, it means they are a student who had Algebra 1 before the class followed by the number of students in that specific course with the same background. If the number started with a PA, it means they are a student who had PreAP Algebra 1. If the number started with a G, it means they had Geometry; PG means they had PreAP Geometry; A2 means they had Algebra 2, BA2, means they had Blended Algebra 2, which is an online-based Algebra 2 course; PA2, means they had PreAP Algebra 2; PC means they had PreCalc; PPC means they had PreAP PreCalc; and C means they had Calc AB. The number followed by each abbreviation is the number of students in that specific course with the same background. This can be seen in Tables 1 - 3.

I also kept track of the student test grades based on each unit to see how they did to compare certain units if something was seen, as well as the overall average grade. Each unit stands for each topic learned in physics. Unit 1 is for One Dimensional Kinematics; Unit 2 is Two-Dimensional Kinematics; Unit 3 is Forces; Unit 4 is Circular Motion and Gravitational Force; Unit 5 is Momentum; Unit 6 is Work, Power, and Energy; Unit 7 is Waves and Sound; Unit 8 is Light and Optics; Unit 9 is Electromagnetism, which entails Electrostatics, Electricity, Circuits, and Magnetism all in one unit. The one unit that differs from Regular Physics and PreAP Physics from AP Physics is that AP Physics does not include Magnetism in Unit 9, and does not do any content from Unit 8. Instead of studying Light and Optics, they study Rotational Motion as that is a topic on the AP Test.

Regular Physics.

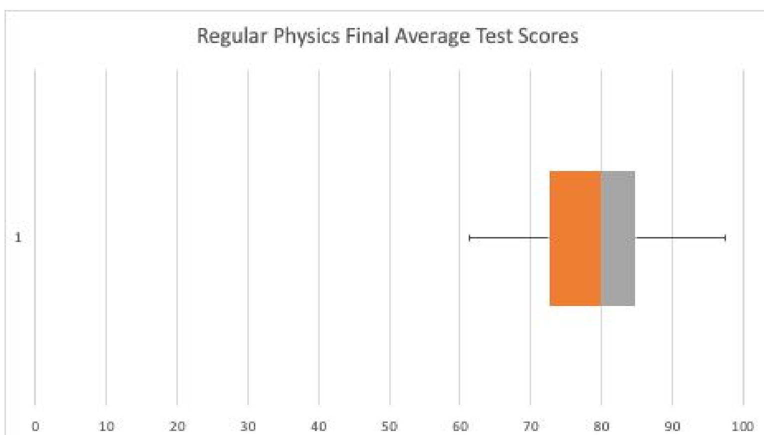

Figure 4. Regular Physics Final Average Test Scores. This figure shows a box-and-whiskers plot of the students' Physics average test scores grades at the end of the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

Once the school year was complete, I looked at the final average test score grades of all the students in many different perspectives. The first perspective I looked at it was through the overall grades. As seen in Figure 4, the median final average grade in the class was 79.9%. Considering that passing the class is a 70%, this seemed to fit that the median should be 80% and was around there for this sample size.

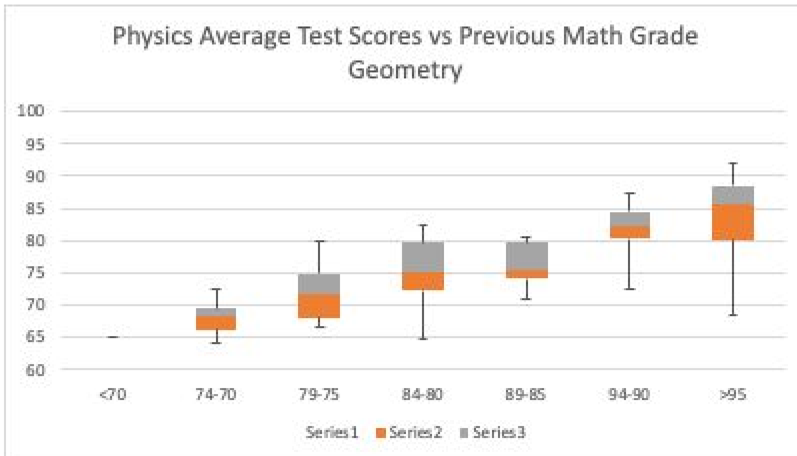

Figure 5. Physics Average Test Scores vs Previous Math Grade in Geometry. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade average before taking the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

From there, I looked at the data based on what math class they had had previously before taking this class. As talked about in the Math Class Observations, 79% of the students who were taking regular physics had only had Geometry, either Regular or PreAP, before taking this course and 18% of the students had taken some level of Algebra 2. When looking at the data I saw that students who had taken Geometry before taking Physics ended getting their final average test scores an entire grade lower than their mathematics grade. When looking at Figure 5, it can be seen that students who received greater than 95% in Geometry before taking Physics received an average test score within the range of 92-68. The median score within this range is around 85%, with the top quartile still being only about 88%, and the bottom quartile being 80%. This is significant because these are mostly your top A students who are receiving about a high B on their average test scores. When looking at this breakdown, these students are the ones near your median for the whole class data, and in the bottom percentile.

Now this is significantly different than what was seen for students who had taken Algebra 2, as seen in Figure 6. The students who had taken Algebra 2 before taking Physics seemed to have gotten an average test score that was around the same range as their average math grade before taking the class. The students were able to get around the same, showing about the range of what the class would have been.

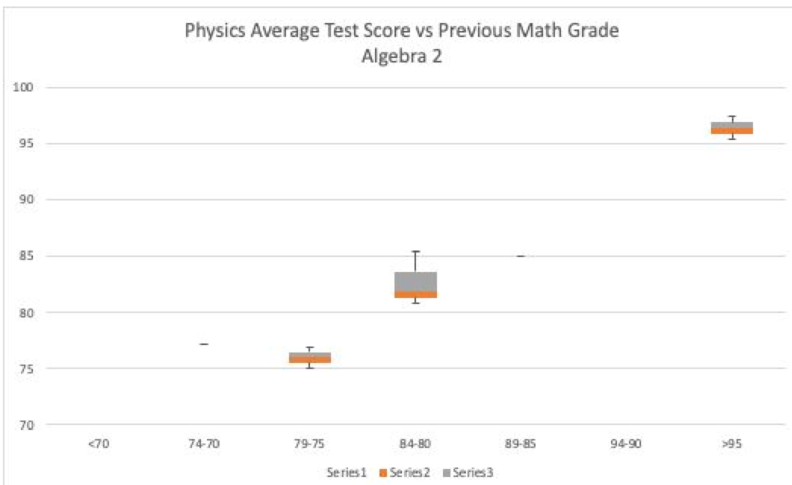

Figure 6. Physics Average Test Scores vs Previous Math Grade in Algebra 2. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade average before taking the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

This definitely made me wonder what could we possibly do to not have this occurring. The reason why I wonder is because it makes it seem as the students have an unfair advantage as physics uses many skills learned in Algebra 2. There could have been students taking it at the same time, which would be the outlier students who did well in the class, but many on average did not seem to. I believe the reason why the students who had only taken Geometry did a grade difference lower was because many of them had not learned the necessary skills to be able to learn more to help them understand more of Physics to their highest ability. Many students could have been focused on how to do the mathematics that they did not understand fully as they did not have the class before yet to be able to help in that realm, which made them not focus as much on the Physics concepts because they were more worried about their skills in mathematics. If they had taken Algebra 2 before taking the course, could the students have been able to learn more and earned that higher degree just by taking Algebra 2 at the same time, or before they took this course? Or is there just a higher number of students who are signing up for this course that we might need to restructure it to accommodate students who have Geometry, since over 50% of the students taking the course have that as their background.

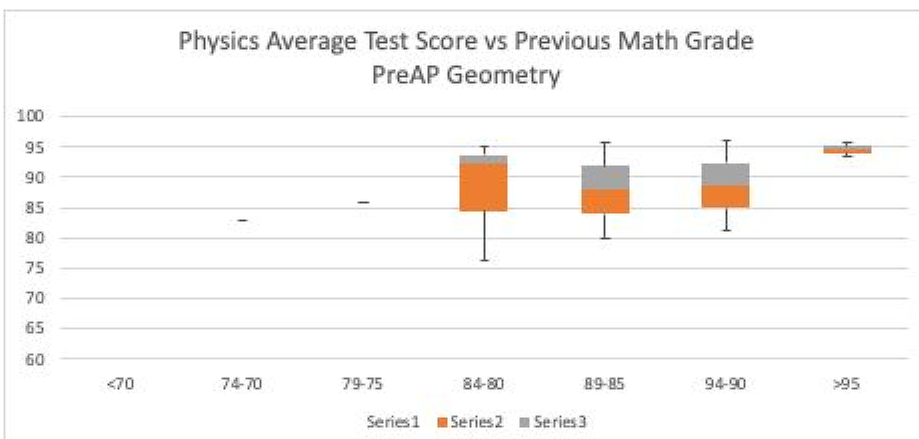

Figure 7. Physics Average Test Scores vs Previous Math Grade in PreAP Geometry. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade average before taking the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

Now when looking at students who had taken PreAP Geometry, another trend emerged as seen in Figure 7. Students who had signed up for the advanced mathematics course ended up getting a grade equivalent to or higher in Physics than in their previous mathematics class. This makes sense as the students who are signed up for the advanced mathematics courses should be students signed up for the advanced science courses, and not the regular science courses as PreAP courses are designed to learn at a faster pace than regular courses. Those students were able to understand the content more, and at a quicker pace to then be able to spend more time in class on other things to be able to make sure they mastered the content. Now each average is still slightly lower than their average mathematics score, except for the 84-80 range, but there could have been students who were taking PreAP Algebra 2 at the same time to skew the data. This is important because it goes to show that they still didn't make it to where their averages where to make one wonder, how should these classes be formatted.

After seeing these things, it leads me to believe that students taking regular Physics courses should have a mathematics requirement of PreAP Geometry, or Regular Algebra 2 or higher before taking Regular Physics, if the curriculum does not change. The reason why is the skills learned in their mathematics courses allow students to learn the proper skills that they are able to apply to their Physics. This allows them to be able to perform to their highest potential in Physics as the teachers can spend more time on concepts and labs to help the students learn the content to the best of their ability as more time is spent on content instead of teaching mathematical skills. As the majority of the students only had Geometry, we are able to see that it impacts their grade an entire letter difference on their average test scores, showing that they do not have the skills to be successful in getting the content to the grade level they previously had. It does not mean they can't take the class, just when they have more skills to be more successful.

Now this is if the curriculum does not change. If the curriculum changed, it should be altered to the level of the students with their knowledge of mathematics skills. It should be stylized where less Algebra 2 skills are being used and instead focusing more on the skills students already have, and taught in a more conceptualized way. This means that the teachers are doing more with the equations, and instead teaching more through labs and experience if a prerequisite is not put into place. This then allows the students to be learning based on where they already are, instead of where we want them to be.

PreAP Physics.

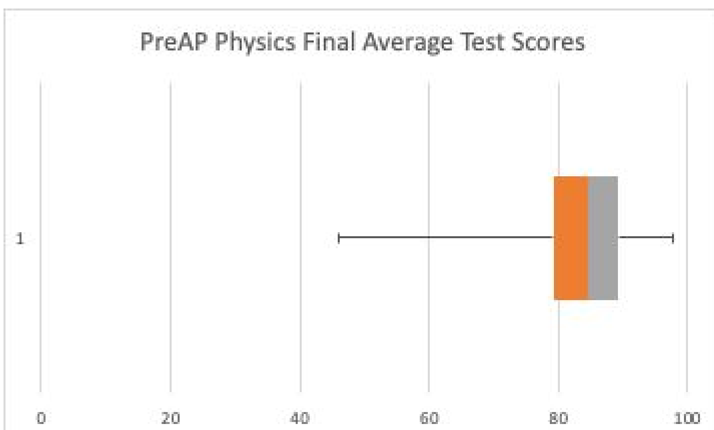

Figure 8. PreAP Physics Final Average Test Scores. This figure shows a box-and-whiskers plot of the students' Physics average test scores grades at the end of the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

For students who took PreAP Physics, I went through the same process. Figure 8 shows a box-and-whiskers plot of the final average test scores for students who had taken PreAP Physics. The median for the class was 84.6%, with a passing grade being above

70%. I then looked at each specific math class they took before the physics class and compared the grades. As talked about in Mathematics Course Observations, 68% of the students had taken some form of Algebra 2, 60% of that percent being PreAP Algebra 2, 28% had taken PreCalc or higher, and 4% had taken PreAP Geometry, Geometry, or Algebra 1.

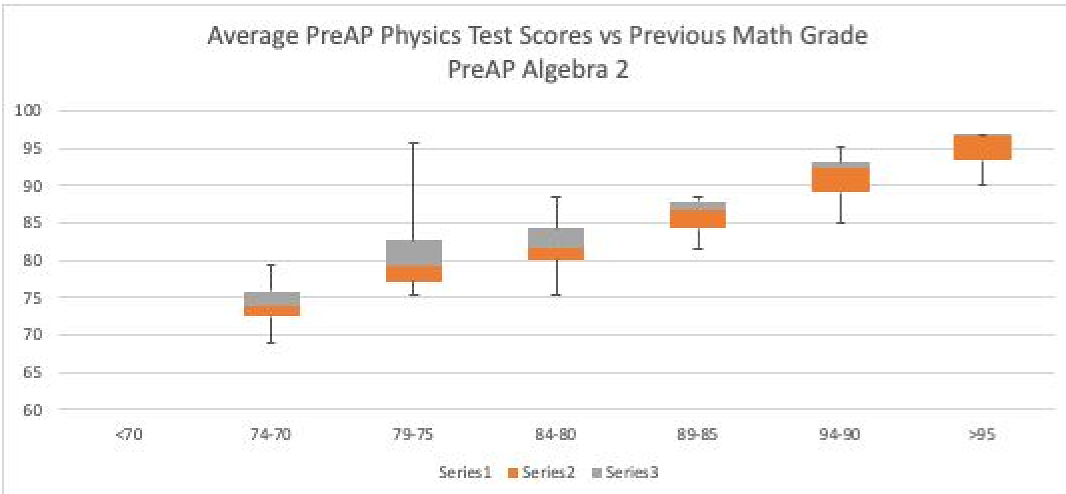

Figure 9. PreAP Physics Average Test Scores vs Previous Math Grade in PreAP Algebra 2. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade average before taking the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

When looking at the 60% of students who had taken PreAP Algebra 2 before taking PreAP Physics, there seemed to be a trend that the students received around the same grade they did in their average Physics test grades as they did in their Algebra 2 class as seen in Figure 9. This was to be expected as students taking advanced mathematics courses do better in advanced science courses. It was also expected as students need skills learned in Algebra 2 for Physics. This way students were able to get a refresher on the mathematical skills needed for the course instead of learning new concepts of mathematics and physics at the same time. This is important because students talk about needing more time or that they do not have enough time to study. This way students are spending less time on learning on their own and can instead focus on one concept at a time, instead of two.

The other trend I saw was for students who were not in the advanced mathematics course route, meaning students who did not take PreAP math courses. The students who had not taken PreAP mathematics courses were students who did not perform to their average mathematics course grade range. The exception came for students who had taken Pre-Calculus before taking PreAP Physics, which was 3% of the students. Pre-Calculus is a class that is taken after Algebra 2. Although there are no prerequisites within the district, many students do not take Pre-Calculus before completing Algebra 2. Pre-Calculus and Physics have a lot of overlap, especially PreAP Physics as it is taught at a higher level and covers many topics that Pre-Calculus covers as well just in terms of conceptual instead of terms of mathematics, yet still use the mathematics to prove it to be correct. Those students who took regular level Pre-Calculus were able to receive the same grade range in physics as they did in their Pre-Calculus course. This means that the Pre-Calculus helped the students learn more mathematical skills that were then able to help more in their PreAP Physics course although they had not been taking advanced mathematics courses. This allowed for the students to be more prepared and know how to do some of the more advanced mathematics used in the course, like in Unit 2.

The other students who had only taken Algebra 1, or Geometry at the regular level had averages that were lower than their mathematics grade range. This means that those students were not able to be as successful as they could have been. It is hard to say if it was because they had not taken PreAP mathematics courses made them have a lack of experience going at a faster pace, or if it is because they have weaker mathematical skills. The students who had taken regular Algebra 2, half of them were able to perform at the same level as their mathematics grade, while the others performed at a lower level. This ends up refuting the trend I saw in the Regular Physics course. It is unsure why this happened as there could have been many other influences that made this data this way. It is interesting to see as students taking regular Pre-Calculus were able to do fine. If the research could have been done longer, it would have been interesting to see if it was due to the rigor and curriculum in Pre-Calculus that is able to prepare the students taking regular mathematics better for PreAP Physics, or if students taking regular mathematics should just take regular science courses. To be able to know more about this would have to have more students who had taken regular Algebra 2 and taken PreAP Physics to see as there were only 7 students who had this situation in the study.

The other thing noticed was that Unit 2, which involved Two-Dimensional Motion, was the unit that the average among the students was significantly lower, a 75.9% versus the 80-85% range I see for the averages of each unit. That unit includes the Trigonomic functions and the Pythagorean Theorem. Students learn these trigonomic functions when they take Geometry, but it seems that students still struggle with the content. When teaching this unit, the teachers talked about how they had to teach a lot more mathematics as students had struggled with many of the triangles and these functions as it seems although the students learn it, either they are not learning it to the extent teachers think they are, or students do not retain this skill as much as their other mathematical skills.

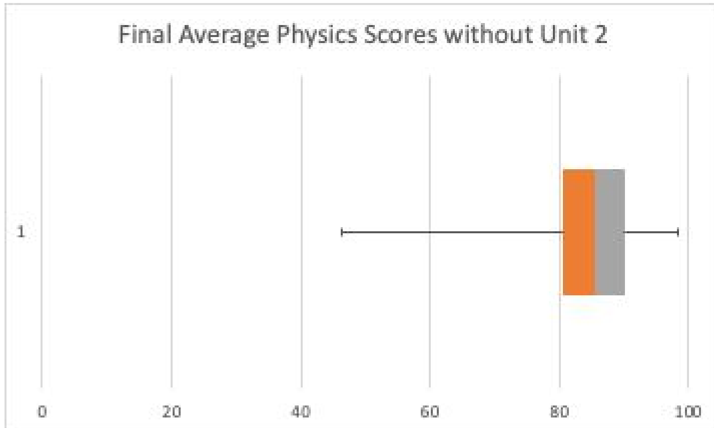

Figure 10. PreAP Physics Final Average Test Scores Without Unit 2. his figure shows a box-and-whiskers plot of the students' Physics average test scores grades at the end of the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

After realizing the significant average drop with Unit 2, I went to reanalyze the data. As seen in Figure 10 compared to Figure 8, it seems that not much has changed on the graph. What has actually changed is the median score went from 84.6% to 85.6%. When looking at the grade breakdowns, it also affects all the average test scores by 1% point increase in the averages. This is not to say it happens for all students, but had happened at the student data we were looking at. This puts into question what more in that unit needs to change to be able to better accommodate the students and have the average be around where the other test averages are. Is there something the teacher needs to do to be able to better equip the students to supplement their learning of the content, or does curriculum need to be revised for this unit to be able to better suit the students, yet making sure that it is still at a different level of learning compared to the Regular Physics course, as PreAP learns content a little more in depth than the regular students.

This tells me that the majority of the students who signed up for PreAP Physics, had the correct mathematical background before taking the class. This also shows that since the majority of the students had PreAP Algebra 2 or higher math courses, the curriculum that was set for the PreAP Physics students was also set at the correct level. The only unit that might need to be looked at to be adjusted would be Unit 2 to accommodate where the rest of the units are at for their averages.

AP Physics.

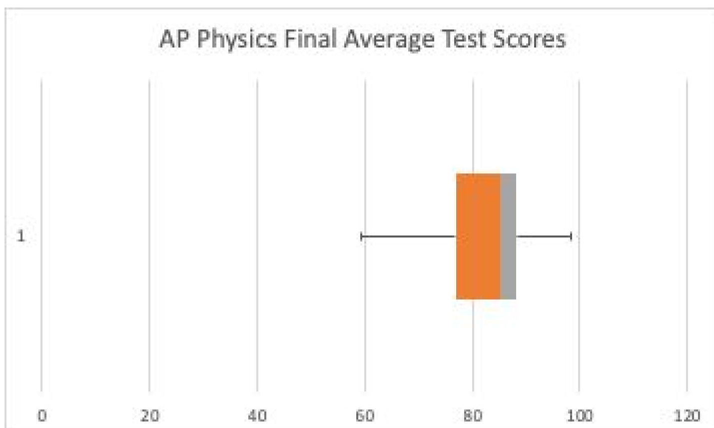

Figure 11. AP Physics Final Average Test Scores. This figure shows a box-and-whiskers plot of the students' Physics average test scores grades at the end of the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

For students who took PreAP Physics, I went through the same process. Figure 11 shows a box-and-whiskers plot of the final average test scores for students who had taken PreAP Physics. The median for the class was 85%, with a passing grade being above

70%. I then looked at each specific math class they took before the physics class and compared the grades. As talked about in Mathematics Course Observations, 4% of the students had taken Blended Algebra 2 or PreAP Geometry, 28% of the students had taken PreAP Algebra 2, 48% of the students had taken some level of Pre-Calculus, and 20% of the students had taken Calculus AB, which is an AP mathematics course.

When looking through the data for students taking AP Physics, it is hard to see any sort of correlation. 96% of the students had taken a PreAP or AP mathematics course before taking AP Physics, all of them passing their previous mathematics course. There was a total of one student who had not had Algebra 2 at any level before taking AP Physics. This student who had received a grade higher than 95% in PreAP Geometry, only received a 75.5% average in their AP Physics test scores. The student was in Algebra 2 at the same time, but does not see Trigonometry until PreCalculus. Since there was only one student, it is hard to draw a conclusion on how this affected them and if College Board's recommendation on students having taken Algebra 2 and Trigonometry at the same time or concurrently would affect the student.

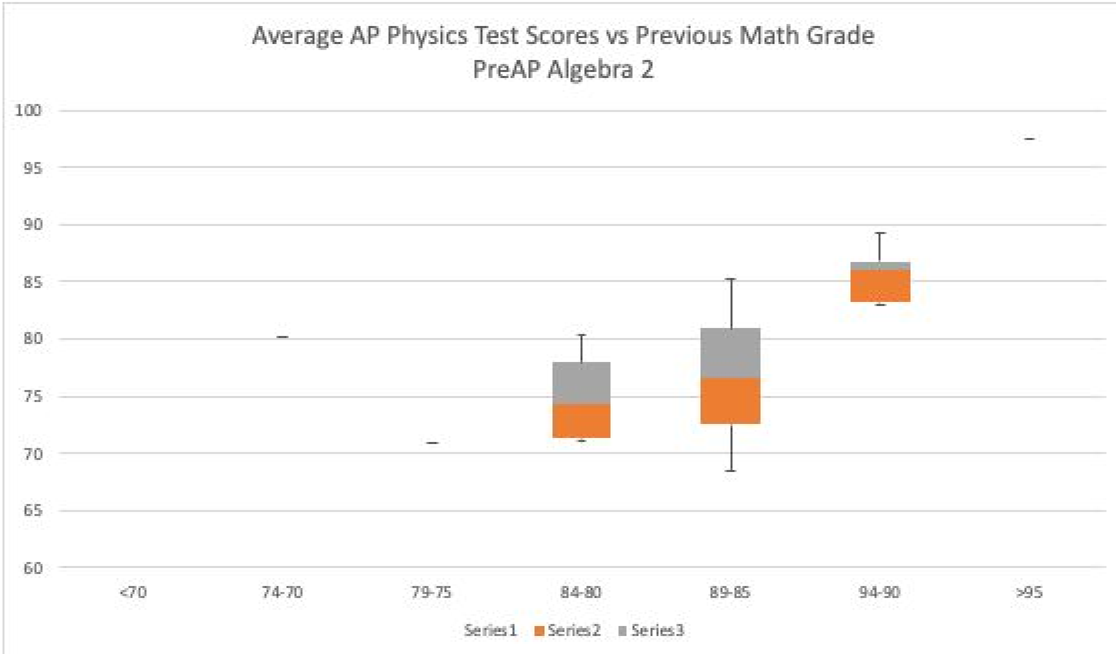

Figure 12. AP Physics Average Test Scores vs Previous Math Grade in PreAP Algebra 2. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade average before taking the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

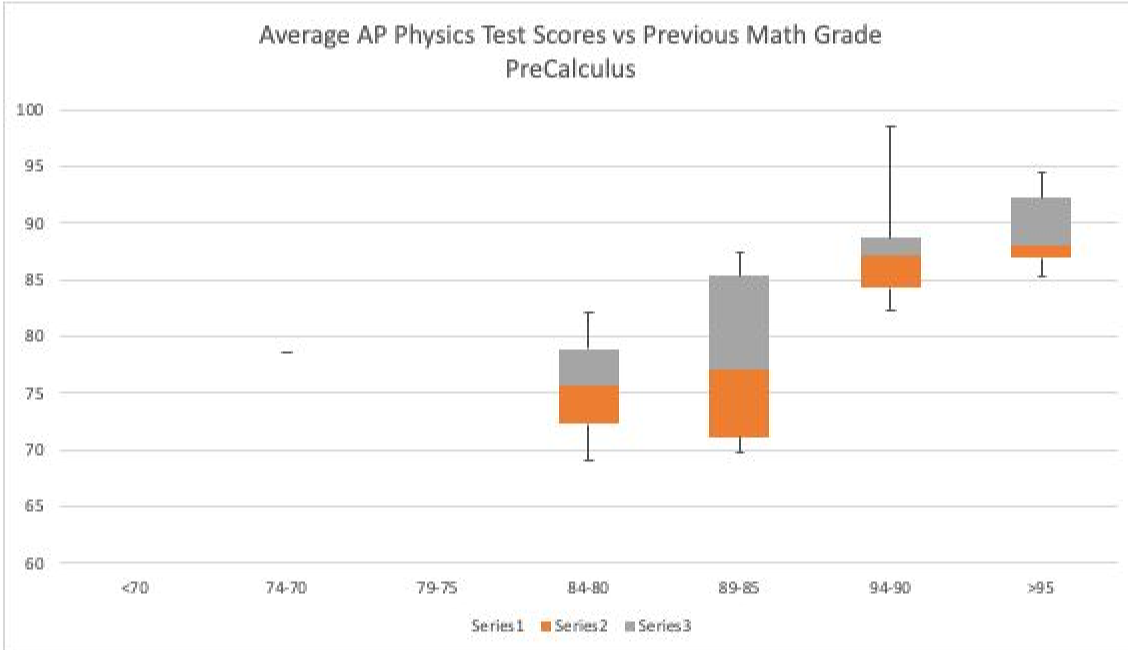

Figure 13. AP Physics Average Test Scores vs Previous Math Grade in PreCalculus. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade average in regular and PreAP PreCalculus before taking the AP Physics Class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

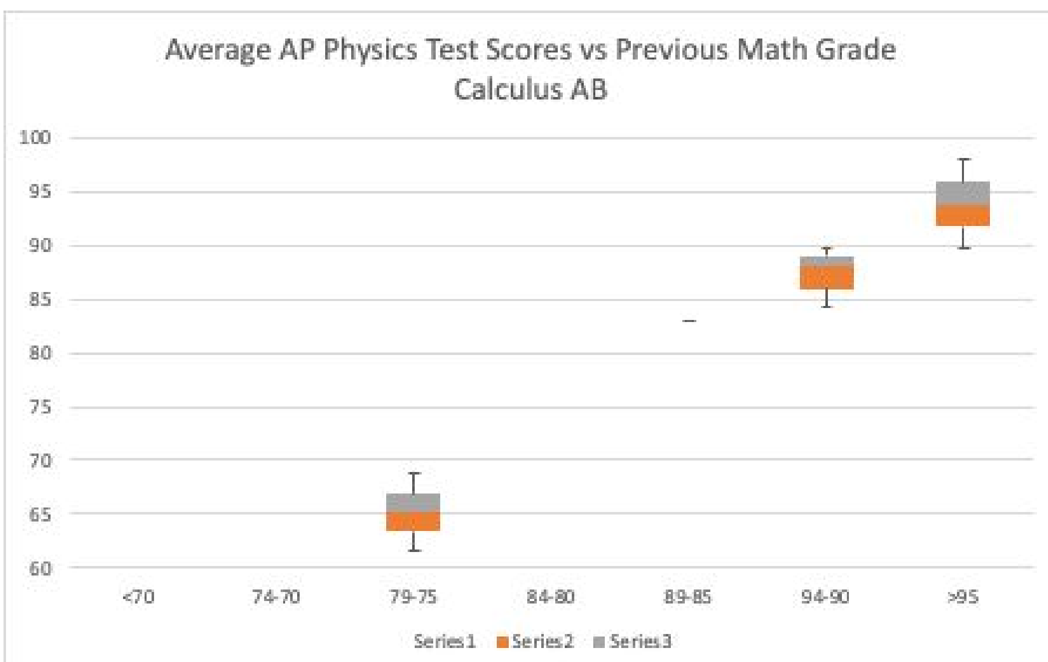

Figure 14. AP Physics Average Test Scores vs Previous Math Grade in Calculus AB. Calculus AB is considered an AP course. This figure shows a box-and-whiskers plot of the students' Physics average test scores grade compared to their mathematics grade

average before taking the class. It is broken down into ranges as seen, and can show the 3rd quartile, median, and 1st quartile of the average test scores.

When it came to looking at the students who had had Algebra 2 before taking AP Physics, their trend of data was not the same as the Physics level. These students seemed to have average test scores that were lower than their previous math grade as seen in Figure 12. Yet this seems to be a theme with all of the students who had taken AP Physics as seen in Figure 13 and Figure 14. What this goes to tell me is that there really is no correlation between a student's mathematics course and AP Physics. It is interesting to see that all the advanced students are the ones signed up for the course, as it should be, but the level of mathematics and the grade you received in your mathematics class does not influence how you will do in this course.

The reason for this could be due to the fact that AP Physics is going by different standards that are set by College Board, and not by the state. This means that the teacher is preparing them for an all inclusive test, which demands more rigor and knowing more of the physics content instead of the math. The teacher then relies more on the students learning the content than using their mathematical skills, which is seen as having more of an emphasis in the other levels of physics that are being taught.

The units that the class averages struggled with the most seemed to be Unit 4: Circular and Gravitational Force, Unit 5: Energy, and Unit 6: Momentum. That might be because the energy and momentum units had content that was covered in the past units on the test, which is the first time many students are forced to be tested on not only that unit, but their recollection on the past units. Those are the units where the students are starting to see more AP like type questions that would appear on the AP test, causing them to not do as well as they might be preparing for a test that is focusing just on those topics, and not other topics that they have already done that build upon the current units. This is something that the teacher needs to focus more on in the future to figure out a better way to help their students make this transition better.

Due to the fact that a passing percent, which is a 70%, on the AP test is considered a 49%, grades had been adjusted to show that a 49% is equivalent to a 70% of actual grades. This means that every test had been altered to have a square root curve, and some possible questions given back based on if 75% of the students had missed the question. It is then inconclusive to be able to say what course and grade you need to have before taking this course. Instead it is advised to listen to College Board's recommendations as the majority of the students seemed to have followed that anyway before taking the class. 96% of the students were in PreAP/AP mathematics courses, and had either A's or B's before taking the course, which is something to continue looking for as those are more of the students who are prepared for the intensity that is in AP.

In July 2018, the AP Scores were released. Scores are given on a 1-5 scale. Of the students who participated in the study and took the AP test 71.4% of the students had passed the AP test, meaning that they scored higher than a 3. This is significantly higher compared to the state percentage who passed the test, which was 23.6%, and the global average, which was 40.6%. Of the 71.4%, 39.3% of those students received a 3, 26.8% received a 4, and 5.4% received a 5, the highest score one could get on an AP test. When looking at the students who did not pass the AP test, those were the students who had not had Algebra 2, poor grades in Algebra 2, or overall poor grades within AP Physics.

Now as talked about above, this seems to match research as they say students taking physics, especially AP Physics, should be the more advanced students in higher mathematics courses. This seems to fit as those were all the students taking it, but having a certain grade with a certain course did not come with conclusive data, yet it is seen that whatever the teacher is doing, they are able to get good results with passing the AP test.

Overall, when looking at all of the data between the Regular Physics, PreAP Physics, and AP Physics results, there seems to be differing suggestions on what the students should be taking before the certain course. When speaking to the teachers, they say it is hard to be able to teach students with a variety of mathematical experience because at times certain kids want a mathematical explanation if they do not know why, while others want to move on. It is hard for the teacher to then explain why students should do the math a certain way or why they do it that way as that is not their area of expertise. This then makes the suggestion that each course should have a minimum requirement of a certain mathematics course for students before taking Physics depending on the course, either Regular, PreAP, or AP. This then gives the teacher a baseline of this is where the students should be at, and can then know what to teach from there. This also allows for them to be able to differentiate from there at a comfort level since they are often differentiating content that is not their area of expertise. This also goes to suggest that these teachers should be offered more professional development that goes to helping them learn how to teach mathematics since they are not trained to do so in their courses before getting their teacher certification. Another suggestion is to redo the curriculum to be able to make sense of where the majority of the students are at. Again, the only issue with this is that it can create a whole variety of abilities that then causes much differentiation within a class to make sure students are not bored, and also not too far advanced they don't understand. So a mixture of the suggestions above together might be the best way.

Summary

The findings gave a lot of insight into many things. As talked about earlier, many of my colleagues did not have degrees in physics, or even a minor in physics. They were still teaching the students the content, without fully knowing it themselves, which is what was seen in research. This then led to teachers only being able to teach the content at a certain level, causing them to not always teach to the standards that are set. The teachers also often see that the students' lack of mathematical background knowledge that they believe is needed for the course also contributes to them having difficulties teaching the content. The teachers talked about how they end up teaching more mathematics content to the students who do not have the background needed before taking the course than they do the content.

Findings also found out that the majority of the students taking Regular Physics had taken Geometry before taking the course. Majority of students taking PreAP Physics had taken PreAP Algebra 2 before taking the course. Majority of students taking AP Physics had taken some level of PreCalculus before taking the course. When students were surveyed they believed that Physics was hard, and very mathematically driven before even taking the course, as was talked about and seen in research that many kids have talked about.

When looking at the students' data, the findings found that students who had taken Geometry before taking Regular Physics had a grade letter lower in difference between their mathematics grade and their physics grade. This showed that students need the higher-level mathematics to be able to have the proper way to be able to really reach their potential need that they have if the course is to continue being taught as currently designed. Students who had taken PreAP Algebra 2 before taking PreAP Physics, their grade letter for their mathematics and their physics grade end up being about the same. This shows that this is the proper class to take before taking the course. For students taking AP Physics, there was no trend really seen to be able to make a consensus for students taking the course.

As we will see in Chapter 5, there are a number of recommendations that can be made on what to do from here so students are properly prepared for the Physics course they choose to take.

CHAPTER FIVE

Conclusion

Introduction

Does the mathematics level affect student success in high school level physics? This was the question that had started this whole process. Throughout this process, I learned many things that I did not know before going into this process. I learned more about research as a whole, and the fact that very little research has been done in this area. Although there are different takes on when physics should be taught to students, if it should be taught to students at all, and to what degree it should be taught at, I was able to learn a lot and take a lot away from this.

During this process, I also figured out a couple different ways to be able to look at my data to be able to come up with some recommendations on what should be done going forward to ensure students' success in physics. Physics is an important subject that has many valuable skills that students can take with them in their future, yet it can only be so productive to students if they are placed in the appropriate class. My research looked at the fact that there were three levels of physics taught at one school, with no prerequisites in place. I looked to see if the mathematics level affects student success in high school level physics and found these results.

Depending on the course, the certain mathematics level range does affect student success in the certain classes. There are other factors that have been taken into account, like student work ethic, and growth mindset, yet there were these trends that were seen throughout the process.

A quote from Meltzer & Otero I had seen that influenced my work was that “most high school physics courses are now – and have always been – taught by teachers who were never specifically prepared for that job, and who have not had the requisite preparation recommended by physics educators (that is, a major or minor in physics)” (Meltzer & Otero, 2014). Between this quote and the knowledge that my district got rid of the prerequisites really influenced my work. Many of my colleagues did not have the type of background many recommend high school physics teachers to have, which I thought was interesting due to what was required from my previous state. I did not realize that the teacher certification process was so different from states on what type of background they required to make you qualified to teach a certain subject. I wanted to know that if not having the prerequisites and not having the background that many physics educators recommend would cause a disturbance between reaching the state standards and the student’s actual ability to perform and learn that material.

Throughout the literature review, there are many things that had been addressed before, but had never been done in a research type of setting to get data to look at. One of the parts that proved the most important part to my capstone was the problems with mathematics and physics. As Baskan, Alev, and Karal said, “students understand abstract concepts in mathematics with the help of science, and they deeply understand science thanks to mathematics" (Baskan, Alev, and Karal, 2010). Many of the students are able to get more help and understand their mathematics more because of the help with science, but many of the students are having trouble deeply understanding the science because they do not have the correct mathematics course to help them be able to do this. If they have the correct background knowledge in their mathematics, as they take their mathematics, the students will be able to learn more and get more out of their science courses.

When looking at the data, this was something that I had also seen. Students who had the mathematical background were able to deeply understand the content being learned as they were using their skills they had learned in both classes. The students who had not had the mathematical background had a harder time getting the truly deeper understanding of the content. They had a harder time to really understand the content because they were focusing on their mathematical skills more which were strengthened by the end of the term. "Often in science, the mathematics needed occurs as an isolated and temporary phenomenon in a non-mathematics setting," which causes many students to remember that one way in memorizing instead of understanding (Hart, 1981). I had also seen this in the data as well as students tried to memorize instead of truly understanding the concepts as they were lacking mathematical skills, instead of using their skills to understand the content more. After looking at the date for each class a little more in depth, and after finding more information about the school policies, teacher background, and based on the student data, I figured out some recommendations on what the school can do to help place students in the proper class for student success.

Counselor Recommendations

The first recommendation is that a prerequisite be put in place. The prerequisite would not be the same for every class, as each class is at a different level, but it would allow for the teachers to know where the majority of the students' background is to help them then know what they need to focus on for teaching. This would be done at the counselor level, as they are the ones who deal with student registration.

For students who want to take Regular Physics the recommendation is for students to have completed Geometry. Students can be successful in this class if they have taken Geometry. If a student passes Algebra 2 with a C or lower, this would also be the class of perfect placement for them as PreAP Physics could still be a struggle for the student, depending how much Algebra 2 was a struggle for them. I would recommend that counselors spend some time looking at students schedules to see this within their transcript before putting them in the class for the most success.

Now this also means that the teachers have to change some of their curriculum to adjust for students not having Algebra 2 skills, which would also mean taking more of a conceptual physics approach where the teachers use a little less equations than they are currently using. They already spend a significant amount of time in the beginning of the class working on mathematical skills, but need to lower some of the mathematics used in the class. Focusing on fewer equations for the units and making it more fitting to geometry mathematical skills, students would be able to have more success in the class.

For students who want to take PreAP Physics, I would recommend that students have had Algebra 2 with a B or higher, or had PreAP Algebra 2. Students who have had either one of these two have been successful in this course. This is what the majority of the students have taken for this course that have seen success. It would be the counselors making that recommendation and making sure that is what they had before taking the class.

The last recommendation for students who want to take AP Physics is to have taken PreCalculus or be taking PreAP PreCalculus. The reason for this recommendation is due to the fact that this is a recommendation from the College Board for this course. Also if students take the regular mathematics courses would need to be in PreAP due to the fast pace of the course. If students took regular PreCalculus they might fall behind. When looking at the data analysis, and after getting AP scores, it was seen that students who had had Algebra 2 and were not taking PreCalculus at the same time as taking AP Physics did not score well on the AP test. This is the reason why for the suggestion.

If the counselors or school does not want to make these changes to the school, there are a couple other recommendations that could happen. Another recommendation for counselors to do is to understand what the student wants to do once they graduate. Figure 15 shows a decision tree on if a student should be able to take physics or not. Figure 16, helps students determine which level of physics they should take. Figure 17 shows when students should take each course if students know that they want to get college credit for physics, but are unsure when they should take it, this helps them with that decision process. By knowing some of these things, that can also help with the decision making process as they might be able to guide them on if they should or should not take physics, as well as what physics course is best suited for them and when they should take it.

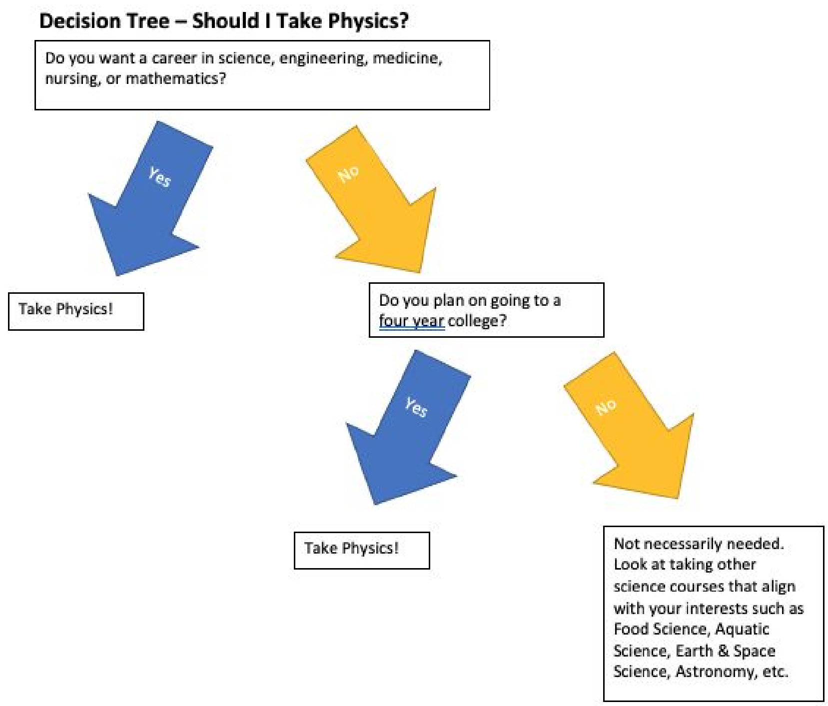

Figure 15 Decision Tree 1. Should I Take Physics? This decision tree can help students determine if they should take physics or not, since they have many options of sciences to take.

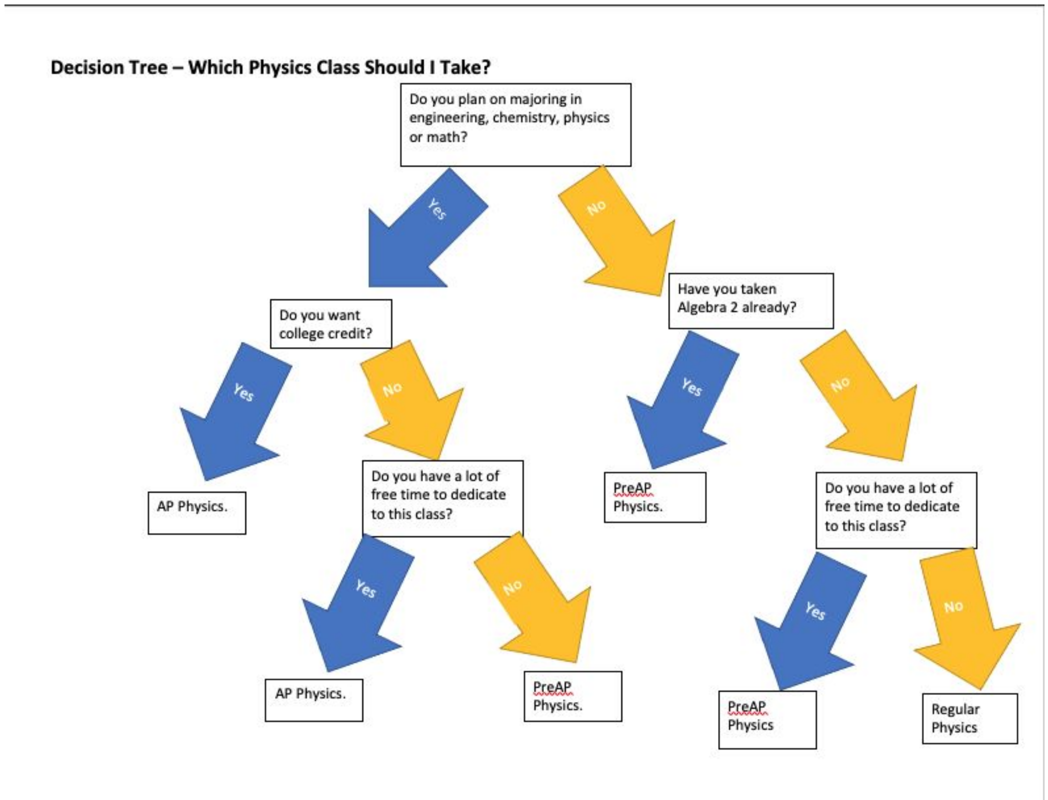

Figure 16 Decision Tree 2. Which Physics Class Should I Take? This decision tree should help students decide which physics course they should take.

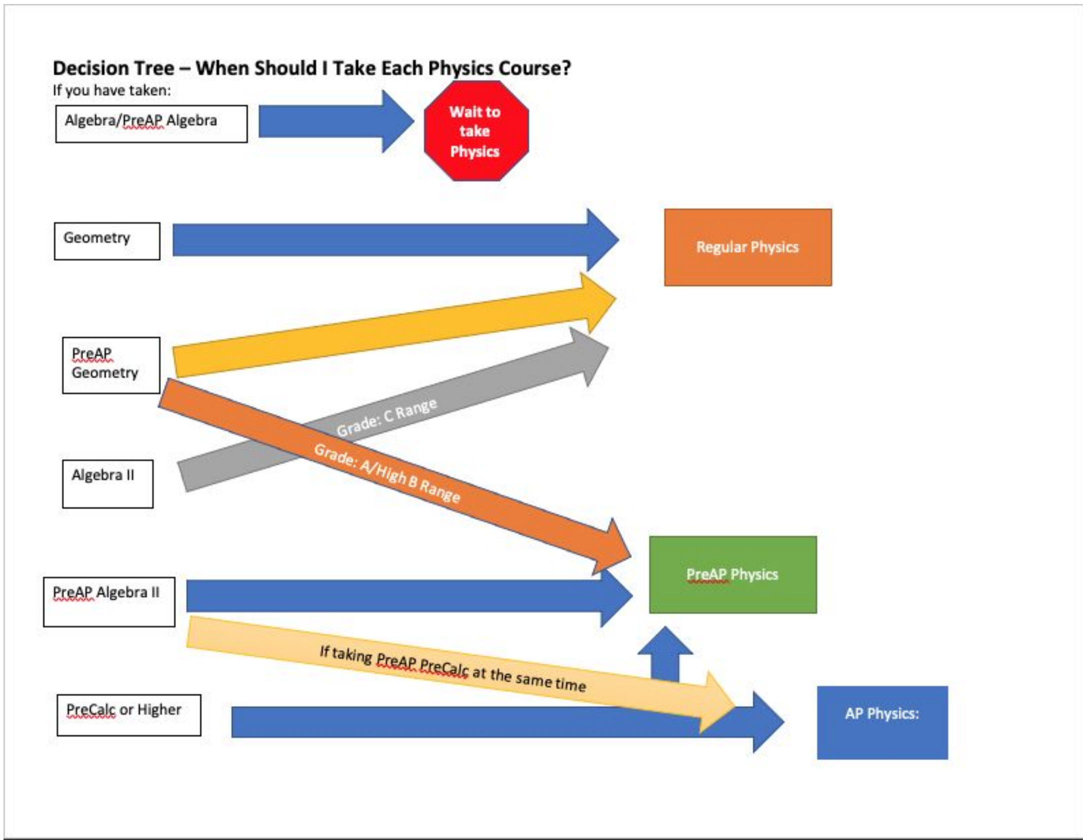

Figure 17 Decision Tree 3. When Should I Take Each Physics Course? This decision tree helps students understand when they should take the appropriate physics course depending on what they have taken.

Changing Curriculum

Another recommendation if the district does not want to have prerequisites would be to change the Regular Physics curriculum to be more of a physics first curriculum and to get rid of PreAP Physics. I said earlier to change the curriculum to fit more students who had a Geometry background as that's what the majority of the students had been taking. To keep the majority of those students taking that class, some curriculum would need to be changed to match where the students' skills already are. But this recommendation is completely different from the other as it is using the Physics First Approach.

The Physics First Approach is teaching more through inquiry based learning and doing very little math. Instead the teachers would be doing a lot more labs with the students for them to learn the concepts through doing, and teaching them based on that. Students would learn their equations through graphing relationships of variables and really only focus on those equations. This way students would be able to take physics, not AP Physics, whenever they wanted to.

In order for this to be achieved, teachers would have to be provided with more equipment to be able to do labs, more training on how to use that lab equipment and labs, as well as more training in the physics content to be able to explain these concepts without any mathematics that many often rely on. It would also be needed for a change in textbooks to be able to help achieve this.

This recommendation would end up helping more students be able to take Physics and the teachers to not worry about when they take it and if they are put in the correct level as there would only be two levels of Physics and AP Physics. AP Physics curriculum would not be changed as that is set by the College Board and should be taken when it is recommended to do so by the college board and after certain classes. This means that only the top students who have had the proper prerequisites for the class take it at the appropriate time. Majority of the students were already doing this, but it could change with more students going to that class from PreAP Physics, but maybe at a later time since the course would be taken away.

Professional Development

If neither one of these are going to be done then there is a recommendation on creating an opportunity for teachers to be able to have professional development focused on two things: mathematics teaching and physics content. Having opportunities for the teachers to have time to know more about the subjects at hand, would allow them to build more within their subjects to better help their students.

By providing professional development opportunities that focused on mathematics teaching, would allow for the teachers to be able to sit down and really have a chance to learn what is changing within mathematics, how things are being taught, and how they as teachers can better teach their students the skills that they learned in mathematics class and to now apply it into physics. It also allows for the teachers to better understand what is being taught at the different mathematical class levels as many of the teachers are going based on their experience of learning mathematics which could range from anywhere eight years or longer since they took the class themselves. This would then also not have so much tension between the science and mathematics teachers as they are now working together and getting some of the same education on what to do instead of always blaming the other teacher. It can open more dialogue between the staff in the departments to figure out more ways to be able to help the students. In the Next Generation Science Standards, it is including more mathematics within the Science Standards, so this is a step that many schools might be taking to better equip science teachers altogether as standards change.

The other professional development that was suggested for teachers to have is one that is Physics content focused. Usually in professional development, it is “science” content that is different from which grade science teachers teach, as well as which content they teach such as Biology, Chemistry, Earth Science, Physics, etc. Having professional development opportunities that are science content specific would allow for more teachers to really get into the content, understand it more, and find ways to be able to better teach their students. As only one in three teachers across the United States have a physics major or minor, it is important to provide this as that means two thirds of the physics teachers in the country do not have many college physics classes in their background. This means that they might not have covered all the content within their college experience to really know the material to help students understand it depending on what level they are learning the material. Having this professional development would allow for them to be able to learn more of the content in depth for their own knowledge, to then better help their students.

The other reason why this is important for them to have is to allow them opportunities to learn more about the material as well as how to create labs for them to do with their students. If a school does have equipment for them to use, many times the teachers do not know how to use the equipment to help them. By providing the professional development with content, it is also allowing them to be able to work on creating and developing labs with the other teachers, and with ones that are experts. This then creates more for the teachers to have to help make the class more inquiry based, which allows the kids to learn more of the physics content without necessarily needing the mathematical background as the others wouldn't be there. Having both of these professional development opportunities would allow teachers to have more knowledge, and more of an understanding and idea on how to help their students be more successful even if they have them at different mathematical levels.

Last Remarks

When doing this study, I was limited as I was only dealing with the population at my school instead of our whole district, which is very diverse compared to just the school. Another limitation within my study was I was only able to do this for one school year, and looking at only one grade level, which can differ every year. I was able to only draw conclusions about one group of students who mathematical schooling might have been different from the grade below it. This can then affect the data some more and not really find a correlation when looking over multiple years.

Some related research projects and recommendations that I would make would be to continue to do this study so that it could be shared. By continuing to do this through the years and continuing with the study can make it more sound, as well as allow more concise decisions to be made about the results.

I have already shared the results with my principal as he wanted to see how it played out. I want to continue educating others about this as well as many in my district and district leaders who are not within science or have ever taught physics. By sharing this data and communicating my results with them, I hope to help more of them understand to start making changes to then share with parents the importance of prerequisites to be able to really help students excel and be more on the road to success instead of just taking the class to get out of high school faster.

If I were able to implement any of the recommendations, I would hope to implement the professional development opportunities for fellow physics teachers in the district, as well as the decision making maps to counselors to give to students. I believe that the decision making maps can help the process of choosing classes, and being sure to be put in the most adequate class. It allows very little on the counselor end, and allows for a lot of self-reflection on the student's end to make an informed decision. I also believe that implementing professional development opportunities in physics and math for physics teachers can only help improve their teaching. It can allow for more opportunities on constructing their curriculum and allow for more opportunities to try new things in their classroom once they are more familiar with the curriculum.

Summary

The idea of school is to have students learn and know more about the world around them. Physics is learning how the world works. Because of how high a level physics is taught, it requires mathematical skills most commonly learned in Algebra II. Having students have the proper mathematics before taking the class allows students to really understand the physics content instead of focusing on how to do the mathematics, which is how many view physics these days, "just another math class".

By having the prerequisite, we are taking the focus away from mathematics and focusing more on the physics and the learning of the world. It allows kids to start learning skills to learn about the world around them, and the importance of it. By having curriculum changes, you are focusing more on what students can already do, and making sure they are able to learn from there and grow more instead of overloading them with too much new content at once. By having professional development, you are empowering your teachers to be able to know more to help their students more effectively. By doing these things, we are allowing kids to see more of the world, as well as knowing more about the world around them.

EPILOGUE

After getting the initial research done for this thesis, I used some of my suggestions to redo much of my class. Having a degree in physics, with a mathematics minor, I have much of the background knowledge on how to teach kids mathematics, and the content of physics to be able to explain it in simple terms, as well as explain the harder stuff to the curious kid. This has given me opportunities to be able to know the material, help create more labs, and make the class more inquiry based to help them learn.

As I was teaching the more advanced courses that used a lot more mathematical skills, and since there are no prerequisites for the courses I taught, I ended up creating my classroom in a way to differentiate it. First I would go through my roster and see if there were any students with mathematical backgrounds that were hugely misplaced in my course. Every once in a while you get students like that. I brought that list to the counselors listing my concerns. Now I did not bring all of them, like students who only had Regular Algebra 2, or PreAP Geometry before having my class. Although the research showed that those students did not get the same grade as they did in their previous mathematics class before getting to physics, I still allowed them in the class as I knew they could still pass the course.

From there I changed what I did in the classroom. The first thing was I put kids in seating charts that were based on their mathematical abilities, as well as taking into consideration those who needed to be put near the front. Doing this made the kids who were not as strong on those mathematical concepts near me to be able to help them with their mistakes as they were close to the board to be able to do the differentiation one on one in the middle of class, without many other students seeing me help. I also had at times kids near their friends who were stronger in math and would often turn to them for help. Doing this provided the differentiation on the mathematical skills the students needed at the time to help them then focus on the physics concepts, instead of the math step they struggled with, making them frustrated and often missing the physics connection.

I also changed my course to allow for more time in labs with the students, which allowed them also more time to play with the equipment and investigate. Doing this also helped students learn the content more, and enjoy the class more instead of focusing on just the mathematical steps. The students still required knowing those mathematical skills, but they seemed to be less focused on memorizing a process, and instead were understanding more of the content.

There was another teacher who also had the same course I did after completing my research. Since we had the same course, we did everything together and the same between our courses so students could not complain about how the teachers did it differently which is what caused them to change in their class rank. However, when doing this, after the three week mark, the other teacher had more students who leveled down out of her class than mine, and had lower grades in the class if the student had Regular Algebra 2 or PreAP Geometry for their background. She too had created the seating charts to be arranged as I had, went to counselors with concerned students, helping students with their math when needed, and doing more labs with her students. The difference between myself and this other teacher was that I have the background in physics, where she does not. She has taken physics courses in college, but does not have a physics major or minor like I have. Therefore she is not able to explain it in more depth or in different ways for students to understand. This is important for a teacher to have to make sure all students understand. This goes to show that even if a course prerequisites are put in place to help teachers focus, they should still have professional development on the physics content to make them more comfortable with teaching physics no matter what level they are teaching as their teaching duty could change from teaching Regular Physics to PreAP Physics quickly depending on staffing needs.

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Appendix

Appendix A
Physics Level Table

Table 1				
Different Physics Levels	Number of students information taken for study	Number of students in the class	Number of Total Classes for Section Offered	Number of Different Teachers Teaching Section
Regular Physics	81	192	7	3
PreAP Physics	91	128	5	2
AP Physics	56	149	6	2

Appendix B

Colleague Consent Form

August 21, 2017

Dear Colleagues,

I am a graduate student working on an advanced degree in education at Hamline University, St. Paul, Minnesota. As part of my graduate work, I plan to conduct research within the semester with your students who is signed up for a physics course and where permission is granted. The purpose of this letter is to ask your permission for you to take part in my research. This research is public scholarship meaning the abstract and final product will be cataloged in **Hamline's Bush Library Digital Commons**, a searchable electronic repository and that it may be published or used in other ways.

I want to study how what previous mathematics course students have taken affect how students do while taking physics. As I have a Physics degree with a mathematics minor, I have seen how many schools have mathematics requirements before taking certain physics courses. I have done research in what other states have for requirements for students who wish to take physics. After doing research and seeing other states having these requirements I want to collect information about if it is really necessary for students to have these requirements before taking physics or not. As students who will be taking physics will be using skills they have learned in math to apply to concepts this semester, I want to see if the class they have taken before this course gives them the skills to succeed without struggling with not understanding due to lack of mathematical skills. The steps to this research process include students being observed in your physics class you teach, their previous mathematics course grade being reported, getting their grade after every test, and students completing a survey after every test for the duration of the 18 weeks of the course. I will also interview you for some of your feedback on how the students did as well as what you noticed when teaching a certain unit.

There is little to no risk for you to participate. All results will be confidential and anonymous. I will not record information about you, such as their names, nor report identifying information or characteristics in the capstone. Participation is voluntary and you may decide at any time and without negative consequences that information about you will not be included in the capstone.

I have received approval for my student from the Hamline University IRB and from the principal of Marcus High School, Mr. Shafferman. The capstone will be cataloged in **Hamline's Bush Library Digital Commons**, a searchable electronic repository. My results might also be included in an article for publication in a professional journal or in a report at a professional conference. In al cases, your child's identity and participation in this study will be confidential.

If you agree that you may participate, keep this page. Fill out the duplicate agreement to participate on page two and return to me by mail or copy the form in an email no later than September 5, 2017. If you have any questions, please email or call me at school.

Sincerely,

Kassandra Surma
5707 Morriss Rd
Flower Mound, TX 75028
469-713-7000
surmak@lisd.net

Informed Consent to Participate in Qualitative Interview

Keep this full page for your records

I have received your letter about the study you plan to conduct in which you will be observing, surveying, and interviewing me. I understand that there is little to no rick involved for me, that my confidentiality will be protected, and that I may withdraw from the project at any time.

______________________________ Parent/Guardian Signature

______________ Date

Participant Copy

Informed Consent to Participate in Qualitative Interview
Keep this full page for your records

I have received your letter about the study you plan to conduct in which you will be observing, surveying, and interviewing me. I understand that there is little to no rick involved for me, that my confidentiality will be protected, and that I may withdraw from the project at any time.

______________________________ ______________
Parent/Guardian Signature Date

Teacher Copy

Appendix C
Parent Letter

August 21, 2017

Dear Parent or Guardian,

I am a graduate student working on an advanced degree in education at Hamline University, St. Paul, Minnesota. As part of my graduate work, I plan to conduct research within the semester with your student who is signed up for a physics course. The purpose of this letter is to ask your permission for your child to take part in my research. This research is public scholarship meaning the abstract and final product will be cataloged in **Hamline's Bush Library Digital Commons**, a searchable electronic repository and that it may be published or used in other ways.

I want to study how what previous mathematics course students have taken affect how students do while taking physics. As I have a Physics degree with a mathematics minor, I have seen how many schools have mathematics requirements before taking certain physics courses. I have done research in what other states have for requirements for students who wish to take physics. After doing research and seeing other states having these requirements I want to collect information about if it is really necessary for students to have these requirements before taking physics or not. As students who will be taking physics will be using skills they have learned in math to apply to concepts this semester, I want to see if the class they have taken before this course gives them the skills to succeed without struggling with not understanding due to lack of mathematical skills. The steps to this research process include students being observed in their physics class, their previous mathematics course grade being reported, getting their grade after every test, and students completing a survey after every test for the duration of the 18 weeks of the course.

There is little to no risk for your child to participate. All results will be confidential and anonymous. I will not record information about individual students, such as their names, nor report identifying information or characteristics in the capstone. Participation is voluntary and you may decide at any time and without negative consequences that information about your child will not be included in the capstone.

I have received approval for my student from the Hamline University IRB and from the principal of Marcus High School, Mr. Shafferman. The capstone will be cataloged in **Hamline's Bush Library Digital Commons**, a searchable electronic repository. My results might also be included in an article for publication in a professional journal or in a report at a professional conference. In al cases, your child's identity and participation in this study will be confidential.

If you agree that your child may participate, keep this page. Fill out the duplicate agreement to participate on page two and return to me by mail or copy the form in an email no later than September 5, 2017. If you have any questions, please email or call me at school.

Sincerely,

Kassandra Surma
5707 Morriss Rd
Flower Mound, TX 75028
469-713-7000
surmak@lisd.net

Informed Consent to Participate in Qualitative Interview
Keep this full page for your records

I have received your letter about the study you plan to conduct in which you will be observing, surveying, and looking at student's grades. I understand that there is little to no rick involved for my child, that his/her confidentiality will be protected, and that I may withdraw or my child may withdraw from the project at any time.

__________________________ ____________

Parent/Guardian Signature Date

Participant Copy

Informed Consent to Participate in Qualitative Interview
Keep this full page for your records

I have received your letter about the study you plan to conduct in which you will be observing, surveying, and looking at student's grades. I understand that there is little to no rick involved for my child, that his/her confidentiality will be protected, and that I may withdraw or my child may withdraw from the project at any time.

____________________________ ______________

Parent/Guardian Signature Date

Teacher Copy

Appendix D
First Day Survey Questionnaire

What do you think about math?
What do you think about science?
What do you think about needing math skills in your science course?
What are some things you know or have heard about physics?
Have you hired a math tutor in the past? ● Yes ● No ● Maybe
Have you hired a science tutor in the past? ● Yes ● No ● Maybe
What are you looking forward to learning about this year?

Appendix E
Teacher First Interviews Questions

What does a typical unit look for you?
What do your lab days look like?
How do you decide lab groups?
What are your tutoring hours?
What is your background in?
How many college physics courses did you take?
What are some issues you have while teaching?
What is something you wish you had more of?
Do you think there should be a math prerequisite before taking physics?
Have you had teacher training in teaching mathematics? If so, are you licensed to teach mathematics?
How do you grade word problems in your class?
Do you believe that student mathematics level affects their success in your physics class?

Appendix F
After Test Interview Questions

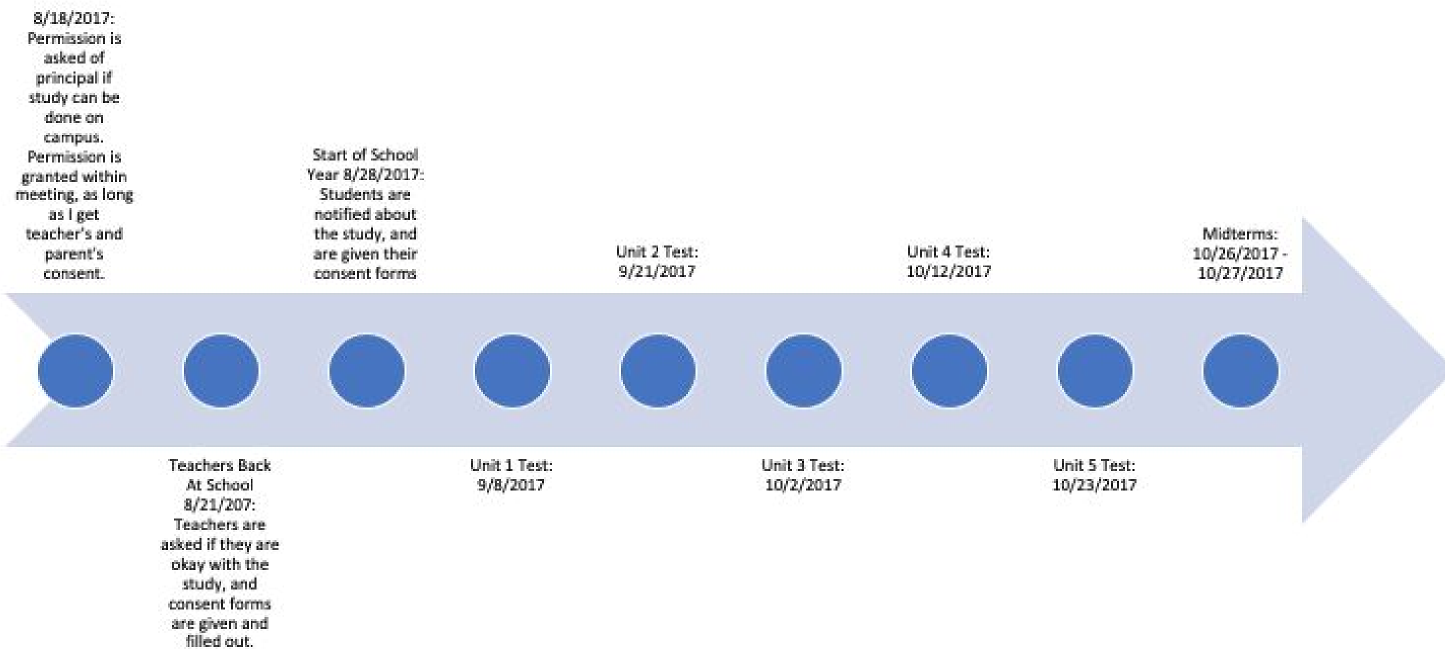
What do you think about the results?
Are there any students within these results that surprise you on doing well?
Are there any students within these results that surprise you on doing poor?
How many labs did you do this unit?
What is something you found interesting about this unit?
Is there something you plan on changing for the next time you teach this unit?

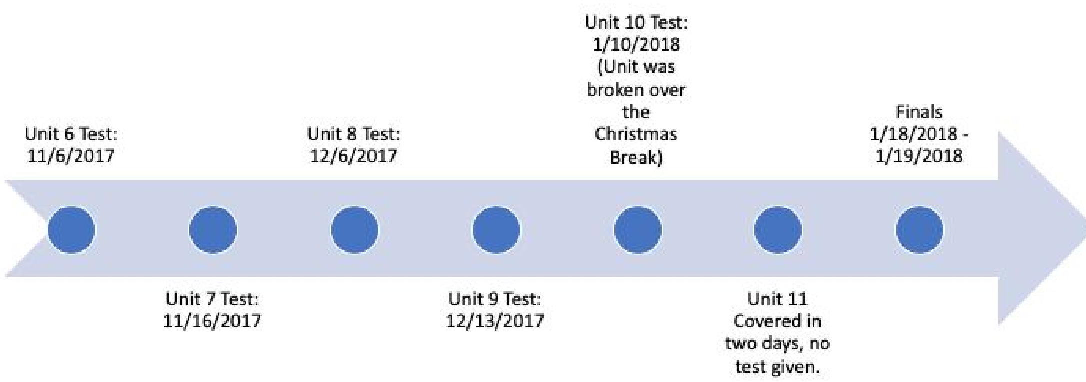
Appendix G
After Test Survey Questions

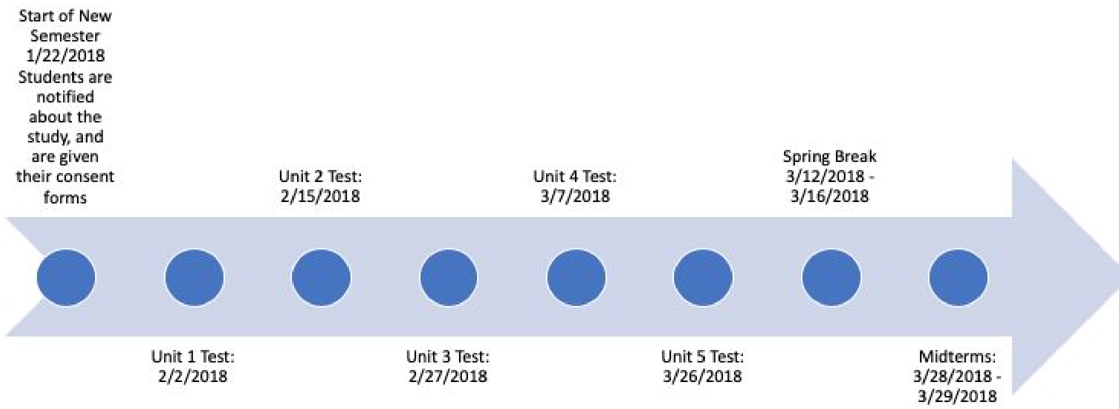
What unit did you just complete?
What grade did you just get on your test?
What did you do to study for this test?
Do you think you got the grade that you deserved for this test?
Did you hire a tutor during this unit?
Did you go to tutoring during this unit?
What do you think helped you in this unit?
What do you still not understand after completing this unit?

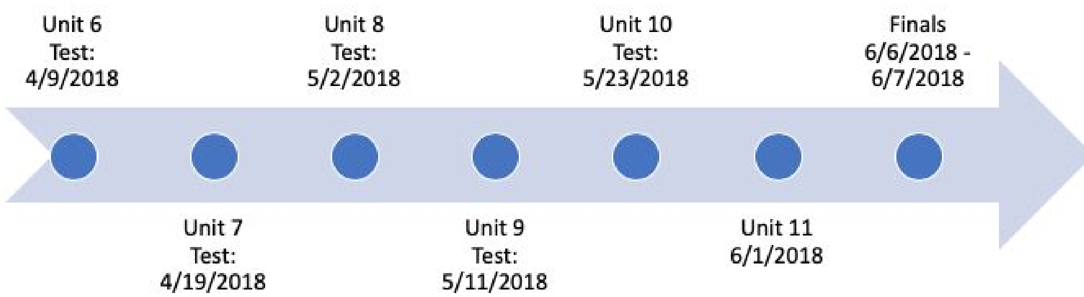
Appendix H

Timeline of Implementation for Physics & PreAP Physics Course.









Appendix I
End of the Year Survey

What do you think about math?
What do you think about science?
What do you think about needing math skills in your science course?
What was your final grade in this physics course?
Should there be a math requirement before taking this physics course?