INCREASING THE PARTICIPATION AND SUCCESS OF STRUGGLING STUDENTS IN HIGH SCHOOL PHYSICS COURSES

By

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CHAPTER ONE

Introduction

Personal Background

"What do you do?" In my experience, this is the most common question people ask when they first meet each other. Regardless of the scenario or group of people I am with, I frequently hear those same four words. Unfortunately, I am never sure how someone will react to my answer. It is tempting to respond with my interests and hobbies, but I know the meaning of the question is to find out what I do for work, so I oblige and tell them I am a high school physics teacher.

"Oh, wow… good for you."

"Ugh… I hated physics in high school."

"Sorry to say, I'm glad I never had to take that class."

"You went through the hassle of majoring in physics and decided to… teach?"

Sadly, more often than not, these are the types of responses I get. Something about referencing school opens up an adult to be blatantly honest with the stranger they just met. They feel it is appropriate to provide me with exactly how they feel about my job and the responses are overwhelmingly negative. If my new acquaintance is curious as to why I chose to spend my time teaching teenagers instead of "making more money doing something else," I always respond the same way.

"Your experience is part of the reason I wanted to become a teacher."

Physics is a subject I love. It is difficult to not get disheartened when I hear adults share their dislike of the subject, their happiness over not having to take it, or their praise for my willingness to stick with it. I openly admit that physics presents challenges to many students. It can be both conceptually and mathematically difficult. However, the struggles students go through in physics have been exaggerated and now have grown into a reason to avoid the subject. When I consider all of my professional goals the same question continues to be at the forefront of my mind: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* The first chapter of this capstone project explains my experience with the negative sentiment around physics and how this question grew to be an integral part of my professional life.

High School

I grew up in Northfield, Minnesota, which is a small town located about 40 miles south of Minneapolis. As a kid, it felt like I lived just outside the southern suburbs of the Twin Cities, but there were subtle differences I did not notice. At the time, I had no idea how much the small amount of isolation impacted the way I viewed my school experience. Now that it has been almost a decade since I graduated high school, I have the benefit of perspective. Conversations with coworkers have opened my eyes to the competitive nature many families face when making decisions about the education of their children. Decisions on where to live are based on school districts and parents fight for advanced placement programs for their six year old kids. By comparison, my school experience was simple and free of politics.

Northfield has three elementary schools that feed into one middle school, and one high school. I knew from early on in elementary school that the kids in my class were going to be with me until I graduated. The idea of losing a close friend because the school district zoning lines said they had to go to a different high school was something completely foreign to me. Everyone from within a ten mile radius went to my school. Children of doctors, farmers, factory workers, business owners, and college professors were all in the same class together. No one decided to move to a different part of town so their kids could go to the *good school*. I mention all of this to highlight the situation in which I grew up. Everyone went to the same school and everyone took the same classes.

High school was the first time there was any meaningful separation between the classes that students took. I decided to take advanced placement (AP) classes in particular subjects and not in others. However, regardless of my choice, I always felt that I was given the opportunity to study all subjects. Whether it was AP biology or regular biology, everyone took the same science in 10th grade. Similarly everyone took some form of chemistry in 11th grade. When it came to core subject areas, this trend had continued for 11 years. I assumed it would continue for the 12th. I was wrong.

In several ways the subject of physics is viewed as an unnecessary luxury, so students do not take it. The state of Minnesota only requires that students take 3 years of science, one of which is either physics or chemistry (Minnesota Department of Education, 2015). The problem for my subject in particular is physics is almost always taken senior year of high school. For the first time students can decide to not take science, so many of them choose not to. Unfortunately, the stigma around physics at my high school was negative in the same way it is at many other schools.

“That’s the really hard class, right?”

“It’s just more math. Why would you want to take another math class?”

“Why would you sign up for that if you don’t have to? Take something easy instead.”

“Is that the class only the nerdy computer kids take? No thanks!”

Misconceptions, a negative reputation, and the freedom to opt out have combined to give physics low participation and a lack of interest by most high school students. Physics is seen as a difficult subject, that is meant for nerds and is not worth taking if students can avoid it. My high school had 10 class sections of biology, 10 class sections of chemistry, and 4 class sections of physics. It is my opinion that physics is at least as important as the other two sciences and it is critical to the next generation of engineers that our society needs. Considering I want to make my life’s work the teaching of physics, the inevitable question that dominates my professional life is: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?*

College

The opportunity to take physics in high school gave me my first exposure to what would become my favorite subject and the focus of study of my four years of college. After going through my senior year of high school, I understood that my choice was not common, I just did not know why. My AP physics course had not been any more difficult or confusing than AP chemistry or AP biology, so what was it? This mystery followed me to St. Olaf College. The physics for majors course track went from 50 students to 30 within the first two years. All while biology, chemistry, and pre-med stayed well over 100. I struggled at times, but it was always worth it once I experienced the exhilaration of solving a complex problem. I viewed my coursework as an interesting and challenging way of understanding the phenomena of our universe. The dislike that others felt toward my subject stayed a mystery to me until my junior year of college.

A confluence of events my junior year gave me a different perspective on physics and suddenly I understood all of the negative feelings and comments I had heard over the years. Three independent factors combined in a way that changed my path toward teaching for the first time in my life. I was taking my most conceptually confusing physics course, I had my least favorite college professor (including all other subjects), and I had my first experience teaching in a classroom. For the first time, physics seemed so convoluted that solving a problem was not satisfying, but infuriating. Even when I solved a problem correctly, I did not understand its significance or find it interesting. This struggle was only amplified by the physics professor I had at the time. He got a bizarre enjoyment from watching students fail in front of the class. Pulling names out of a hat, he would ask students to solve a random problem on the front board. If they failed, he would openly laugh at how far off they were. The added stress of being mocked only hardened my dislike for physics. Coincidently, I was simultaneously taking my very first education class.

As a part of this course I was required to spend time observing and helping in a high school physics classroom. That experience could not have happened at a better time. While observing, I noticed students who were experiencing the exact same struggles I was. They were not being mocked by the teacher, but I could tell they had no idea what they were doing or why they were doing it. They were frustrated, lost, and wanting more than anything to never see another physics problem in their lives. Finally, I was able to understand those exact feelings on a personal level. During my time helping those students an urge started to take hold of me. I wanted to do everything I could to help students never feel that way about physics again. I realized I did not want to have a job using physics, I wanted to spread my love for physics in a way that gave everyone a chance to understand, succeed, and enjoy it. Those moments were the very first time a crucial question starting forming in my mind: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?*

Teaching

A year after my first experience teaching in the classroom, I graduated from St. Olaf College with my Bachelors of Arts in Physics and was ready to begin my teaching journey. I decided to enroll full time as a graduate student in the Master of Arts in Teaching program at Hamline University. After two years of study, research, discussion, creation, and student teaching I was finally standing in my own classroom ready to tackle the challenge I had put in front of myself. At least, I thought I was ready. It turns out that the amount of new experiences and struggles teachers face during their first year is staggering. My second year included a change of school and my first chance to teach physics. It was another whirlwind that brought me back to two objectives: to be better and to get back to solving the question I put in front of myself in my junior year of college.

Similar to most young teachers, I had a grand goal of walking into my first classroom and changing everything for the better, only to be confronted by reality. I was faced with an aged curriculum and a flawed culture. As I battled through my first year teaching physics, I noticed the same disheartening struggles I once felt and now know lead to the prevailing negative perception of physics.

"I can't do this Mr. O'Neill, I'm not good at math."

"We get to go to Valley Fair right? That's the only way my dean convinced me to take this class."

"More problems? Why can't we spend more time DOING physics?"

Many of my own students experienced the same frustration I noticed the very first time I helped in a classroom. Putting my own spin on the curriculum done by other teachers at my school was not enough. The time had come to look back at the question that drove me towards teaching to begin with and find the answer to: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?*

Summary

Physics was the first class I took that felt as though I was taking a subject that was not meant for everyone. Unlike previous core classes, the decision students made was not whether they would take AP or regular physics, it was whether they would take physics at all. Sadly the answer was usually a resounding no. The negative stigma that surrounded the subject confused me until my junior year in college when I finally understood. The struggles in math, conceptual confusion, and desire to give up all became clear. At the same moment, I got the opportunity to help out in a classroom for the first time. Explaining the wonders of physics to students brought back my love of the subject and helped me realize I did not want to give up on physics, I wanted to create a way for students to experience the joy of understanding without the overwhelming struggle. After a year of teaching physics I have seen all of the difficulties physics can present to a student and am setting out to create a curriculum that will lead to increased participation and success for all students.

The process used to achieve this goal is explained throughout the next three chapters of this capstone. Chapter 2 is a detailed literature review of physics education that delves into relevant concepts and issues. It highlights the opinions of experts within the field and sets a foundation for the current reality of high school physics curriculum. This analysis of pivotal research serves as a reference point for the new curriculum I introduce in the project portion of this capstone. The context, framework, audience, and goals of this curriculum are described in chapter 3. This chapter sets the stage and explains the rationale for new physics curriculum. After adding my contribution to the landscape of high school physics education through my project, chapter 4 provides an overview and conclusion to my capstone. This includes the implications and limitations of my new curriculum along with critical take-aways and future steps.

CHAPTER TWO

Literature Review

Introduction

High school is a unique life experience because all adults can look back on their lives and form a memory of what it was like to sit in math class or English class. Sadly, that phenomena is not true when it comes to the subject of physics. Participation in high school physics is drastically lower than other science subjects. It is common for physics teachers to have encountered a negative bias and stigma towards physics in high school, in college, as a teacher, and in personal communications. The inherent mathematical nature of the subject matter and the low priority placed on it as a graduation requirement, have perpetuated the negative stereotype that physics is a difficult and unnecessary luxury at the high school setting. Due to these factors, physics teachers need to turn their focus toward answering the question: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* Before any steps can be made to move forward, it is important to know how schools and society got to this point. This chapter is a literature review that outlines the current reality of high school physics education.

There will be readers of this literature review who did not take physics in high school. Therefore, the logical place to start is by outlining the structure and obstacles of teaching physics. These subjects are discussed in the Role of Graduation Requirements, Standards, and Mathematics, which is the first topic of this literature review. After highlighting the barriers facing the popularity of physics and the success of high school physics students, it is important to make a full account of the current literature surrounding physics education. This is the focus of topics two and three of this literature review: problem based learning (PBL) and inquiry based learning (IBL). This in depth look at successes and challenges in the field of physics education will provide a strong pedagogical base to build on. The final hurdle of achieving the goal of this capstone requires a change in the stigma surrounding physics and a renewed student interest in the subject. Therefore, the final topic of this literature review focuses on the subject of culturally responsive teaching (CRT). The review of these four topics provides the current and best work of the professional community. It offers a crucial starting point from which to build, because physics teachers need to know where they are as a community before they can progress to a brighter future.

The Role of Graduation Requirements, Standards, and Mathematics

Before delving into the successes and challenges of a particular teaching strategy, it is important to first highlight the unique circumstances and obstacles surrounding high school physics. Graduation requirements, standards, and mathematics are all issues that pose a challenge specifically to high school physics. The goal of this capstone is to increase the participation of high school students in physics and increase the success of students who are struggling in physics. A review of the placement of physics in the current educational system is required in order to accurately address all possible barriers to greater success of physics students in our schools.

Graduation Requirements. High school graduation requirements are not identical in all 50 states in the U.S., but there are many similarities. Unfortunately, none of them are good for the subject of physics. The level of attention placed on science as a whole is less than other common core subjects like English. Most states require four years of English, while science is usually 2-3 years, and in only one case four years (Education Commission of the States, 2018). The Education Commision of the States (ECS), which produced this compiled list, also indicated that no state requires physics specifically. The curriculum created by this capstone will be implemented in the state of Minnesota, so the (Minnesota Department of Education, 2015) will be used as a specific example. The Minnesota Graduation Requirements (2015) used very similar language to other states when it came to categorizing science subjects. Only three courses of science are required, one of these courses must be biology, and one of the courses must be either physics or chemistry. This categorization clearly emphasizes biology over the two subjects labeled as physical sciences. It would seem as though chemistry and physics would have similar amounts of high school students based on the fact that technically students can choose either subject. Unfortunately, the traditional order of science classes taken in high school creates a stark discrepancy in the number of students in each content area.

Traditional Order of High School Science. Though there has been talk in recent years of attempting to change the order that science courses are taken in high school, the traditional order of biology, then chemistry, and then physics is still the most popular method. This order was originally created because of the level of math needed to succeed in each subject (Glasser, 2012). Glasser (2012) highlighted that early high school students do not yet have the mathematical capability for the more complex physics course and the traditional method proceeds naturally from least difficult mathematically to most difficult. Physics as the final stage of high school science has become a staple in schools around the nation (Huang, Mejia, Becker, & Neilson, 2015). Unfortunately, this tradition of physics as the final science course can lead to fewer students taking the subject when the time comes.

This concerning trend has recently been amplified in the state of Minnesota. Historically, nearly all Minnesota students start high school by taking an introductory physical science course as a 9th grade student and then begin the traditional route of biology-chemistry-physics as a sophomore. However, in the spring of 2019 the decision was made to switch the 9th grade science subject from physical science to earth and space science (Minnesota Department of Education, 2019). This process has no inherent flaws, but when it is combined with graduation requirements that necessitate only three science courses and an option for either chemistry or physics, students frequently enter their senior year not needing to take physics. By senior year, all science requirements for graduation will have already been met, so for the first time in their schooling, students are given the choice of whether or not to take science. Inevitably, some decide not to continue. The ramifications of this decision have been amplified with the recent change in 9th grade subject matter and standards. If Minnesota students complete three years of science as is required in order to graduate and then decide not to complete a fourth year, they will graduate having never been exposed to even introductory physics. It is worth delving into the math-focused rationale for ordering the science subjects and whether the level of mathematical difficulty warrants the subsequent drop in students participating in physics.

Physics Standards and Benchmarks. Once again, due to the location where the following curriculum will first be used, the Minnesota State Standards are used as a reference. All physics teachers in Minnesota start the formation of their curriculum around the 8 core physics standards set out by the state, and the corresponding 25 benchmarks (Minnesota Department of Education, 2009). Of the 8 major standards, 6 include critical portions that require mathematics and 8 of the 25 benchmarks are specifically math-centered. Science Standards MN (2009) used the verb *calculate* as the way students show their understanding of the 8 math focused benchmarks. The level of math required for proficiency ranges from simple 3-variable algebra equations, to more complex 6-variable algebra equations. These concrete requirements from Science Standards MN (2009), show a clear need for mathematics in the subject of physics. The next logical discussion is whether this connection between math and physics is vital enough to warrant waiting to teach physics until students have had more time to improve their mathematical skills.

Math is Critical. An in depth examination of the research surrounding physics education showed the critical role math proficiency plays in understanding and succeeding in physics. In a study of 200 students taking introductory physics, a pretest on algebra and trigonometry showed a correlation between high scores and future success in physics (Hudson & McIntire, 1977). Hudson and McIntire (1977) found that students needed more than just math ability in order to achieve success in physics, but inadequate math proficiency led to poor physics performance. A similar study of 360 students showed scores on a math fluency pretest were strongly correlated to future success in physics (Leopold & Edgar, 2008). These studies highlighted the possible benefits of students' increased mathematics knowledge prior to taking physics. However, teachers often regret the lack of math proficiency of students as they enter physics courses (Sanjay Rebello, Cui, Bennett, Zollman, & Ozimek, 2007). Results from the study by Leopold and Edgar (2008) reaffirmed the notion that most students have an inadequate level of math ability. For some teachers, the lack of required math knowledge pushes them to set aside time in their own class to teach math directly (Redish & Gupta, 2010). Physics teachers feel they share the responsibility of teaching math in order for students to achieve high levels of success (Bing & Redish, 2009).

It is common for teachers to desire the very best for their students and give accordingly, but the reliance physics has on math is uncommon and deserves further discussion. Math and physics are subjects that feed off each other, where many of the best conceptual math problems are actually concepts of physics. Redish and Gupta (2010) expanded on this thought and discussed how physics makes powerful use of math and puts practical meaning to it. Physics necessitates an effective and efficient use of math and becomes increasingly reliant on it in higher level physics courses (Bing & Redish, 2009). The need to work through more math as a part of a science course can be seen as tedious to some high school students, but in reality it is critical to understanding and modeling the physical world they live in. Redish and Gupta (2010) emphasized that physics is not all about understanding and manipulating equations in spite of the fact that introductory physics courses often present hundreds of variations of equations. The struggle that students feel when attempting to solve physics problems frequently is not due to a lack of mathematical knowledge, but rather the inability to properly connect a physics concept with the correct mathematical tools (Sanjay Rebello et al., 2007). Physics shares an inseparable connection to math that causes difficulties for students that cannot be ignored. Prior to introducing new curriculum it is necessary to take a deeper look at why students are not able to efficiently apply mathematics to physics concepts.

Conceptual vs Mathematical. The two greatest challenges of the subject of physics are conceptual complexity and mathematical difficulty. As noted previously, research has found physics teachers lament the inadequate math proficiency of their students. However taking teacher complaints, even if justified, as the sole issue facing physics education would be an injustice to the intricacies of student learning. The complex conceptual nature of physics certainly plays a role in student struggles, but researchers disagree on its connection to the necessary mathematical problem solving. Leopold and Edgar (2008) asserted that entering a physics course with inadequate math ability hinders a student’s development of conceptual understanding. Alternatively, Bing and Redish (2009) contended that students struggle with the math involved in physics because they lack understanding of how it relates to conceptual complexity. Both sets of researchers agreed the mathematical and conceptual aspects of physics are intertwined, but do not offer any data supporting a comprehensive way to move forward and create a curriculum to help struggling students.

Every physics teacher must make a decision upon which concept they will spend more class time focussing, conceptual understanding or mathematical problem solving. A recent study was conducted to test whether it would be more effective to spend the majority of class time focussing on manipulating equations to solve problems or developing thorough conceptual understanding. The study involved a teacher in a public high school setting teaching an introductory physics course with a math focus followed by a conceptual discussion, and the other with a conceptual focus followed by a mathematical verification (Sadaghiani & Aguilera, 2013). The same pretest and posttest were given to both groups and Sadaghiani and Aguilera (2013) broke down the data based on which group showed a greater increase from one test to the next. The mathematical group gained and average of 16%, while the conceptual group gained an average of 25%. This data had an incredibly small sample size, but it offered an insight into the possibilities of a curriculum that focuses more on conceptual understanding prior to mathematical practice. Students who are able to do the math but don't have a firm grasp of the concepts, struggle to know where to start or understand what the numbers mean. On the other hand, students who understand the physics concepts are able to explain the situation and set up the problem. These skills are beneficial and transferable to future topics even if the math is not correct the first time.

Summary. Teaching high school physics presents a specific set of challenges that must be understood before positive changes can be made. The placement of physics as the final class in the traditional order of high school science, combined with only needing three courses to satisfy graduation requirements, has resulted in 12th grade students around the nation choosing to not take physics with little to no high school ramifications. The mathematical and conceptual difficulty that physics presents along with the traditional style in which it is typically taught has furthered the stigma amongst high school students that physics is an unnecessary challenge to face senior year. However, physics offers a deeper understanding of the world and if presented properly can be seen not as a struggle, but as an exciting and worthwhile course. The unique challenges that face the future progression of physics education require that teachers grapple with the question of how to create a curriculum that will increase the participation and success of high school physics students. The key to changing the narrative is finding the most effective, interesting, and relevant way to present the subject of physics. The following three sections of this chapter break down research of the most promising ways to increase both the success of students taking physics and the overall participation of students in physics courses.

Problem Based Learning

A critical way to combat the challenges expressed in the previous section is to revamp the curriculum away from a traditional math and equations focus and toward something more intriguing. Problem based learning (PBL) is a curriculum that offers students an opportunity to solve extensive, multi-step, real-world problems. Teaching physics through PBL has been attempted, celebrated, critiqued, dismissed, and argued over the last few decades. The goal of this section is to find out whether PBL is a possible replacement for traditional physics teaching. To adequately answer that question it is necessary to delve into the definition of problem based learning, the issues facing it, and the benefits of using it as the basis of a curriculum.

Definition of problem based learning. PBL is the all-encompassing phrase that is used to describe a version of teaching that presents content in the form of real-world problems to solve. However, the way this large idea is implemented can vary greatly depending on how it is interpreted by each individual teacher. At its most simple PBL has been defined as an instructional method defined by the use of problems as a way for students to learn problem-solving skills and acquire knowledge simultaneously (Albanese & Mitchell, 1993). However, compilations of previous research show definitions have evolved and grown to be more complex. English and Kitsantas (2013) created one such compilation and found PBL defined as:

> A systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic (real-life) questions and carefully designed products and tasks… an instructional method in which students learn through facilitated problem solving that centers on a complex problem that does not have a single correct answer… an approach that engages students as researchers, prompting students to learn how to ask important questions, design and conduct investigations, collect, analyze, and interpret data, and apply what they have learned to new problems or situations. (p. 130)

Other researchers have taken the broad concept of PBL and focused on a specific aspect in order to appropriately frame their work. One such example is using PBL to move away from equations and toward problem solving using concepts and principles

(Docktor, Strand, Mestre, & Ross, 2015). This conceptually focused version of PBL is defined as “guiding students to identify principles, justify their use, and plan their solution in writing before solving a problem” (Docktor et al., 2015, p. 1). PBL can also be defined not by what it is, but rather the student results it is meant to provide. Baran, Maskan, and Yasar (2018) focused on PBL as “an approach designed to develop desirable learner characteristics such as research skills, self-confidence, responsibility and cooperation through activities in which learners work individually or in groups” (p. 222). Regardless of the specifics of each definition, these researchers all highlighted what PBL is meant to accomplish. However, there are also inevitable drawbacks and hurdles that stand in the way of the success of this curriculum.

Issues facing problem based learning. No particular teaching strategy is a silver bullet that can solve all problems. Like all other strategies there are drawbacks to implementing a curriculum based on PBL. The strongest critique in the literature surrounding PBL placed it in a group of strategies that employ a minimally guided approach (Kirschner, Sweller, & Clark, 2006). Kirschner et al. (2006) concluded that there is no data to support the technique of minimally guided teaching and that it only serves to increase the cognitive load placed upon the students. This belief that PBL leads to struggles in knowledge acquisition was reported in earlier research. Albanese and Mitchell (1993) noted a concern that a broad based curriculum centered on PBL could lead to lower general knowledge scores due to a lack of time to adequately cover material.

The most common warning related to the implementation of a PBL focused curriculum was not a concern over the amount of knowledge that could be appropriately taught to the students, it was a cautionary message related to a change in the role of teacher and student. In order for PBL to be successful, students must take responsibility for their learning. A necessary result of this shift toward greater student responsibility is a need for the teacher to create a learning environment that supports student regulated learning (English & Kitsantas, 2013). Rather than presenting content and controlling the classroom, teachers must be willing and able to provide students with the structure to monitor, evaluate, and reflect on their own learning (Baran et al., 2018). A worthwhile assertion given by Albanese and Mitchell (1993) is their belief that the best possible result can only be achieved when PBL is implemented with extreme care.

Benefits of problem based learning. Despite the barriers in front of PBL, the majority of the research around the topic showed if it is done correctly, it can be hugely beneficial to the teaching of high school physics. The strongest support in the literature surrounding PBL was a direct response to the work of Kirschner et al. (2006). This response by Hmelo-Silver, Duncan, and Chinn (2007) asserted that PBL is not a form of minimally guided instruction and it requires extensive scaffolding to reduce the cognitive load placed on the students and produce ideal results. If prepared and taught appropriately "students learn content, strategies, and self-directed learning skills through collaboratively solving problems, and reflecting on their experiences" (Hmelo-Silver, C.E., Duncan, R.G., Chinn, C.A., 2007, p. 100). Finally Hmelo-Silver et al. (2007) dispelled any notion of the teacher as a bystander by affirming the need for direct instruction and highlighting that completing PBL first results in students learning more during lecture.

Aside from the increased results achieved by any specific physics class, PBL showcases fundamental qualities that prepare students for future success. As a student centered approach, students learn by doing and just as importantly, they learn how to learn (Baran et al., 2018; English & Kitsantas, 2013). Most challenges students face throughout the rest of their lives require the ability to learn new things on their own and adapt to succeed. The traditional model of teaching physics is equation-centered and focuses on the numbers, but advanced physicists solve complex problems by using a strategic conceptual approach that sets up the entire solution before applying the necessary math (Docktor et al., 2015). Approaching physics education with a problem based focus helps students “develop real-world skills such as solving complex problems, thinking critically, and analyzing and evaluating information” (English & Kitsantas, 2013, p. 129). Physics and the jobs surrounding it are irreplaceable for the progress of society and PBL provides students with real-world problems to prepare them to answer questions that have not even been asked yet (Holubova, 2008). This benefit cannot easily be measured in the statistics of a posttest, but it is a critical reason why PBL needs to be incorporated into the high school physics curriculum.

Summary. Problem based learning is a way of teaching that can be defined and structured in many different ways. However, when it is taught effectively and provides students with the opportunity to solve complex real-world problems, PBL can be massively beneficial to the success of students in physics and beyond. It is not without challenges and Docktor et al. (2015) was likely correct that it is unrealistic to expect high school teachers to adopt it wholesale, but it deserves a place in physics education. It is not the only effective way to teach physics, but PBL should be a central part of building a successful high school physics curriculum.

Inquiry Based Learning

The benefits of giving students the opportunity to solve real-world problems by teaching through problem based learning are crucial to a successful curriculum, but PBL leaves out an essential part of what it means to study and perform science. If implemented in a suboptimal way, it could help students learn how to solve complex problems but never encourage them to ask questions and wonder. For this reason, more than one strategy is needed to teach the full breadth, width, and nature of science. Inquiry based learning (IBL) is a type of curriculum framework that gives students the opportunity for curiosity, investigation, and discovery. The merits and drawbacks of IBL have been argued over in science literature over the last few decades. This section delves into the definition, possible flaws, and benefits to be gained from implementing IBL as a curriculum framework.

Definition of inquiry based learning. When teachers are focused on outside factors like standardized tests and performance evaluations it is easy to forget to allow time for students to have the crucial experience of the true nature of science for themselves. IBL is a basis for instruction that holds firm to the belief that students learn science best when they are given opportunities to experience the authentic practices of scientists (Harris & Rooks, 2010). The field of science is more than a collection of data, set of information, or store of knowledge. Science is the process of discovery that has moved our civilization forward for millennia. IBL focuses on students mastering content by carrying out investigations that broaden understanding and guide them through the process of science (Harris & Rooks, 2010). For all its grandeur, the details of IBL are not particularly well-known or easily defined. *A Framework for K-12 Science Education* was created in part to answer that question. The following eight practices were set forth as essential aspects of a science curriculum:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analysing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

(National Research Council, 2012, p. 49)

These eight elements lay the groundwork for using inquiry as an essential tool in science education. By conducting investigations, students begin to view science itself as the process of inquiry that leads to the evidence for all scientific discoveries (Bodzin & Beerer, 2003). Despite the time and effort put forth by the National Research Council (2012), there are still many detractors of IBL who question its ability to function effectively as a basis for a curriculum.

Issues facing inquiry based learning. The process of discovery that is created through IBL and heralded by part of the science education community, is disparaged by others who believe it is an unrealistic expectation that leaves students high and dry. The published work that is in the most glaring opposition to IBL is once again Kirschner et al. (2006). In their opinion, IBL is simply one of many forms of instruction that does not offer enough support and belongs in a large category defined as minimal guidance. The overarching concern was these strategies set students loose to explore and expect them to arrive at a full understanding on their own.

Every strategy and innovative curriculum has opposition, and the negative sentiment and concern over teaching strategies such as IBL should be studied and understood rather than swept aside. Even the researchers who support IBL as a valuable aspect of teaching science acknowledge that it includes significant shifts and challenges in classroom management in order to succeed (Harris & Rooks, 2010). These modifications do not resolve easily and are made more difficult when teachers are not prepared to implement inquiry based teaching. Rather than letting the students loose to explore and discover on their own, IBL requires teachers create a comfortable, respectful, and collaborative learning environment, as well as a detailed series of coherent learning experiences (Harris & Rooks, 2010). Inquiry based instruction affords choice in hands-on and minds-on activities while providing strong forms of structured guidance (Hmelo-Silver, C.E., Duncan, R.G., Chinn, C.A., 2007). The flaws and drawbacks of IBL experienced in classrooms throughout the country are not due to any inherent problems with the curriculum, but rather the complexity of its implementation. If done correctly, IBL can offer benefits for all types of students.

Benefits of inquiry based learning. Cultivating a generation of scientifically literate students requires more than just an understanding of content knowledge. IBL offers the opportunity to teach students to appreciate and participate in the act of doing science. By teaching the nature of science and sparking curiosity, teachers can set students on a path to become independent inquirers and analysers of the natural world (Bodzin & Beerer, 2003). Engaging in scientific activities and investigations provides students with a context to apply scientific knowledge in their own life (Harris & Rooks, 2010). Instructing students through a science-as-practice approach highlights the connection between our current scientific knowledge and the process it took to achieve it. This method prepares the next generation of scientists to solve problems humanity cannot yet understand or even know exist.

Alongside the idealistic image teachers have for the growth of their students toward scientific literacy, appreciation, and application, IBL has also shown the ability to improve test scores and minimize achievement gaps. Multiple recent studies have highlighted the benefits of well-crafted IBL. One such study of 58 randomly chosen high school students, showed the inquiry based group reached a significantly higher level of achievement than commonplace curriculum following 4 weeks of separated instruction (Wilson, Taylor, Kowalski, & Carlson, 2009). The same study indicated a large racial achievement gap in the commonplace instruction group of students and no tangible gap in the IBL group. A much larger study of over 17,000 students in a large urban district in the Midwestern United States resulted in significantly higher pass rates on high-stakes standardized exams amongst students in science classes that focused on an inquiry based approach (Hmelo-Silver, C.E., Duncan, R.G., Chinn, C.A., 2007). This 3-year study showed historically disadvantaged groups had increased motivation and engagement, which led to a reduction in the achievement gap of urban African American boys (Hmelo-Silver, C.E., Duncan, R.G., Chinn, C.A., 2007). These studies are a part of a growing body of evidence that indicates IBL is not only a successful basis for curriculum for all students, it may also be especially beneficial to the student groups who currently need the most help.

Summary. Inquiry based learning is a basis for instruction that focuses on teaching students the nature of science alongside the content knowledge. This combination of inquiry investigations and guided instruction give students the opportunity to learn critical concepts through the act of doing science. Implementing IBL in the classroom can be a new and difficult challenge for teachers. It requires the appropriate classroom environment and guided content in order to succeed. When implemented effectively, IBL has shown the ability to improve student test scores and lower achievement gaps, all while cultivating increased science literacy and a greater appreciation for the nature of science. If teachers are going to successfully combat the challenges facing physics education and increase the participation and success of students, IBL needs to be a part of the curriculum.

Culturally Responsive Teaching

Problem based learning and inquiry based learning offer a framework of science teaching that has the ability to increase success and equity for science students, but this goal cannot be fully achieved without a dedicated focus on culturally responsive teaching. There is no end goal or perfect curriculum to create in order to be a culturally responsive teacher. Culturally responsive teaching (CRT) is a relentless pursuit to ensure all students can experience equity and success regardless of any external factors that affect their lives. It requires deep introspective reflection and a willingness to change on the part of the teacher. Every student, in every school, around the world is a different and unique individual who brings their own experiences, beliefs, and personality with them to school. If teachers want all students to experience success they must adapt and evolve to best serve the ever changing students in their classrooms.

Why is culturally responsive teaching important? Teaching is a skill that requires constant adaptation and improvement in order to maintain mastery. There is no one idealistic way to perfect and then maintain throughout a career. Technology has fundamentally changed this entire generation of students and it would be foolish to think teachers can maintain the same practices they had in the middle of the 20th century. Given that the majority of the school-aged population in the United States are students of color, meaningful racial, cultural, and linguistic connections to instruction are growing increasingly important (Brown, 2017). With the growing problem of racial achievement gaps, it is worth recognizing the many well-documented studies highlighted the benefits of culturally responsive instruction for students of color (Brown, 2017). This broad view of the changing landscape of education can be helpful, but ultimately it is an incomplete way to approach CRT.

Finding success as a culturally responsive teacher is about so much more than the macro trends of the United States. CRT requires teachers to become effective "for all children, regardless of their academic ability, ethnicity, socioeconomic status, family structure, sexual orientation, and ability to speak English" (Grant & Gillette, 2006, p. 292). Society creates its own biases and inequalities surrounding race, gender, religion, culture, sexual orientation, appearance, and disability (Grant & Gillette, 2006). It is absolutely critical to the success of all students that teachers do not perpetuate these inequities in their classroom. All students must be given the opportunity to succeed and it is up to the teacher to navigate through all of the outside factors and create a judgement free classroom based on equity and merit.

Crucial categories of effective culturally responsive teaching. The successful implementation of CRT does not have the same obstacles as problem based or inquiry based learning. The researchers who study CRT do not have to spend the same amount of time and energy focusing on proving the value of it as a teaching method because the majority of educators agree on its critical importance. The difficulty of including more CRT in the classroom is that it is a complex and ever changing issue that varies widely based on the population of students a teacher is attempting to serve. The best work that can be done is in creating categories of importance and offering advice as to how to incorporate them in a way that is culturally responsive.

In order for teachers to improve on their ability to offer opportunities for success for all students, they must have a basis for assessing their own instruction. Several frameworks for CRT have been created throughout the last few decades and one such system broke it down into five categories: content integration, facilitating knowledge construction, prejudice reduction, social justice, and academic development (Hernandez, Morales, & Shroyer, 2013). Hernandez et al. (2013) created these categories after analyzing and synthesizing the previous works of Banks (1980 and 2004), Sonia Nieto (2004), Gloria Ladson-Billings (1992), Geneva Gay (2000), and Villegas and Lucas (2002). Each category was then broken down by Hernandez et al. (2013) to include critical aspects necessary to achieve CRT. A summary of those works are as follows:

- Content integration - foster positive teacher-student relationships, hold high expectations for all students, instructional strategies based on the needs of a diversity of backgrounds and learning styles
- Facilitating knowledge construction - build on what the students already know while assisting them in learning to be critical independent thinkers
- Prejudice reduction - build a positive, safe classroom environment in which all students are free to learn regardless of their race/ethnicity, social class, or language
- Social justice - encourage students to question and/or challenge the status quo in order to aid their development of sociopolitical and critical consciousness

- <u>Academic development</u> - create opportunities in the classroom that aid all students in developing as learners to achieve academic success (Hernandez et al., 2013)

The ideas shared in these categories are not groundbreaking new ideas. Many educators would simply describe them as facets of great teaching. The fact that these practices are well known does not make them any easier to implement. There are new and different circumstances in every section, of every class, every semester, of every year. CRT takes time, energy, humility, and grit in order to continue to offer the best opportunity for all students.

Summary. Culturally responsive teaching is a critical and unavoidable step in ensuring all students have the best possible opportunity to succeed. There is no end goal to CRT. Instead it is a relentless pursuit to block out the bias and inequality of the society around us, in order to create a classroom based on equity and merit. The process of improving the ability to instruct using CRT takes self reflection, adaptation, and deep care for students. If done well and combined with the appropriate curriculum, it can improve test scores while also strengthening the quality and confidence of the students leaving our classrooms.

Conclusion

The purpose of this literature review was to provide an overview of the current difficulties facing high school physics education and offer a summary of frameworks that could improve the quality and interest of high school physics curriculum. The question that guided the literature review was: *How can a curriculum be created that will increase* *the participation and success of struggling students in high school physics courses?* The role of graduation requirements, standards, and mathematics was the focus of the beginning of the review in order to highlight the unique position of physics in the high school setting. These three factors contribute to lower participation, less success, and a more negative bias towards physics than the other subjects of science.

Confronted with this overwhelming problem, the next three sections were studied in order to lay out the best possible route toward improving physics education. Problem based learning offers students the opportunity to solve real-world problems that spark interest and provide critical skills for future success. Inquiry based learning sparks curiosity and allows students to question, investigate, and discover. It gives students the chance to learn the nature of science by experiencing the scientific process and learning the content knowledge at the same time. Culturally responsive teaching is a never ending process of creating a classroom that provides the best possible opportunity for all students to experience success. The rest of this capstone is the explanation and creation of a curriculum that focuses on these three frameworks in order to answer the question: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* Chapter 3 details how the information from this literature review can form the foundation of new curriculum that includes the positive aspects of PBL, IBL, and CRT without an uncertain attempt at wholesale changes.

CHAPTER THREE

Project Description

Introduction

As a high school student, I experienced some success in my physics class, but more importantly, I enjoyed it. Those two experiences were not very common among students at my school. I did not realize why until a few years later when I was in college and came to a crossroads. The physics course I was taking was difficult, frustrating, and for the first time not enjoyable. This course took place at the same time I was given a chance to volunteer in a high school classroom. This confluence of events changed the course of my life. I realized I wanted to help students feel success and enjoyment from physics, rather than frustration and discouragement. After graduating college, getting my teaching licence, and teaching for three years I was brought back to the same goal and overarching question: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?*

The process of answering that question and fulfilling one of my goals as a teacher required a deep dive into the current state of physics education. The literature review presented in chapter two of this capstone highlighted the unique issues facing high school physics and laid out a few of the most well respected frameworks for science curriculum. Throughout this chapter I lay out the plan and describe the process I took in order to create new curriculum that aligned with these frameworks and offers all students a better chance at success in physics.

Basis for Curriculum Development

The constraints of state standards and the inherent mathematical difficulty of physics have grounded most physics classrooms in teacher-centered instruction. This reality has further entrenched the subject of physics with the bias of being difficult, tedious, and unenjoyable. Despite these unfortunate circumstances, there is a strong push from part of the physics education community for change in the form of new curriculum frameworks. Understanding physics provides a knowledge base and skill set that is widely sought after in the medical, technological, economic, and engineering job markets. It is crucial to the advancement of our society that students are equipped with the skills to question, investigate, analyse, and solve real world problems. These skills are the center focus of curriculum created around problem based learning (PBL) and inquiry based learning (IBL).

Scope and Sequence

The valuable skills and extensive positive student outcomes that are possible through a curriculum focused on PBL and IBL would logically lead to their widespread adoption. Unfortunately, so far that possibility has not been realized. The main reason these frameworks have not been adopted by more teachers is the difficulty of undergoing a full instructional, grading, and classroom environment change to one framework or the other. Even the researchers who support PBL and IBL suggest they be implemented as part of a curriculum and not pushed as a wholesale change (Albanese & Mitchell, 1993; Harris & Rooks, 2010). For this reason, my goal was to create a new piece of curriculum for every major physics unit that will fit in with previously developed curriculum and align with the standards of both PBL and IBL frameworks.

The structure of physics units are usually repetitive due to the complex conceptual and mathematical nature of the content and need to scaffold upon each previous topic. A traditional approach includes direct instruction of new content, a lab activity to support understanding of the topic, a multitude of practice problems to highlight all possible variations, formative assignments to check understanding, and a summative test. Aspects of these steps are crucial to a deep understanding of the content, but it is common for students to get bogged down and uninterested during the drill and kill of seemingly endless practice problems. My goal is to replace this aspect of the unit sequence with new activities and projects that require students to ask their own questions and solve real-world problems. In order to meet this goal, different pieces of new curriculum were specifically created for each of the six main topics of introductory physics. The key aspects of PBL and IBL were a constant focus throughout as well as a built in opportunity for students to bring in their own perspectives and ingenuity. These modifications to the current curriculum give students some control over their learning while maintaining the integrity and building on the success of already well established practices.

Avoiding the Ideology of Perfection

Most new teachers have wide eyes and big goals of making their own path and changing the system for the better. The reality is more complex and difficult. While new teachers might have great ideas for new activities and a different way to approach education, their veteran coworkers have experience and their own take on teaching that has been tested for years, if not decades. Full scale curriculum change requires intense collaboration with job-alike teachers and approval from the school administration. It cannot simply be created, implemented, and approved by one individual teacher with a dream. This reality is the second reason why my curriculum development project is not one stand alone *perfect* unit of physics. The goals of understanding set out by previous teachers are tried and true, based on state standards, preparation for college, and what is best for the students.

Assessment of New Curriculum

Similar to the process of creating new curriculum, assessments cannot be implemented in a vacuum. The development, modification, and improvement of formative and summative assessments is constant and never ceasing. As a result, the curriculum developed does not include new summative assessments. Instead, it is incorporated into the existing curriculum and evaluated by comparing the test scores of my students to those of students from previous years on a unit by unit basis. Pre-tests and formative check-ins will also be used to gather information on student progress before, during, and after completion of the new curriculum.

While monitoring the progress of students through each physics topic, the proficiency and success of the new curriculum proposed in this capstone project will also be assessed. The plan to incorporate these new labs and activities into the existing curriculum allows for a comparison of student performance to that of previous years based on the summative test for each unit of study. There is value in qualitative observations from a teacher that one curriculum was more effective than another, but new learning experiences can not be accepted year over year unless they also prove to increase the scores of students quantitatively on summative assessments.

The final way in which the new curriculum proposed in this capstone project will be assessed is on a different and macro level. The question that drove this entire capstone was: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* To fully achieve an answer to that question there is a broader underlying goal of increasing the number of high school students who are taking physics courses. The percentage of students enrolled in a physics course within the school, will be monitored to see if the negative stigma around the subject of physics is being broken down by a less intimidating and more enjoyable curriculum.

Understanding by Design

The process of creating new curriculum centered on problem and inquiry based learning will involve new learning activities and experiences. It is crucial that these new components have a clear path to student learning. I will be using the Understanding by Design framework to ensure that the student-centered activities have clear priorities and purposes (McTighe & Wiggins, 2012). This framework was built upon a backward design model that follows a three-step plan of first identifying desired results, then determining assessment evidence, and lastly planning learning experiences and instruction (McTighe & Wiggins, 2012). This process involved choosing what I want the students to know, understand, and be able to do, deciding how they are going to show evidence of their understanding, and creating the instructional experiences that will most effectively help them succeed. Staying steadfast to this framework guaranteed I did not create content only because it is fun and interesting, rather with an end goal in mind.

Project Setting

The curriculum that I developed for this capstone project will be used in the high school where I teach. It is important to know a little about that school in order to have a frame of reference to use when evaluating the curriculum. All of the information given about the school will be averages and approximations over recent years, rather than exact values. It is an urban/suburban high school in the state of Minnesota. There are about 1,700 students whose demographics are 57% White, 18% Black or African American, 12% Hispanic or Latino, 9% Asian, 1% American Indian, and 3% two or more races. Free/Reduced priced meals are given to 42% of students, 12% qualify for special education support, and 4% are English language learners. Graduation within four years is achieved by 93% of students, with 4% continuing after. Of the students who graduate, 83% take at least one concurrent enrollment college course within their four years.

In particular, the curriculum I developed is for a regular physics course. This course is meant for 12th grade students and is the lowest section of physics offered at the school. It is neither an AP associated course nor a concurrent enrollment affiliated course. It is a course meant for any and all students and it usually comprises a majority of students who will not be pursuing a science-related career. I believe that, regardless of the status of this course in the school, it can be a course that sparks curiosity and offers opportunities for skill-building and deep understanding.

Project Timeline

After the groundwork and planning for the completion of this capstone project had finished, the true work of curriculum development remained. I completed this work during the summer of 2019. I used the school-year of 2018-2019 to take notes and brainstorm aspects of current curriculum that can and should be changed. Throughout the summer these notes were used as a way to reflect and as a launching point for new curriculum development. Throughout the creation of the new material it was critical to stick to the best practices of the understanding by design framework. Therefore, the process began by matching the state physics standards to the conceptual units already in place in my school, in order to create curriculum with the end goal in mind and maintain continuity. This step was followed by developing desired outcomes and assessment evidence for each topic that match the learning targets presented to the students. Lastly, this project provides the critical information a teacher would need to facilitate and the materials needed for the students to participate in the new learning experiences. This work will be incorporated into existing curriculum and implemented for the first time during the 2019-2020 school-year.

Conclusion

Every new teacher learns in their first year of teaching that curriculum cannot be implemented in a vacuum and the same holds true for the creation of new curriculum. The rationale and methodology used to create specific pieces of curriculum are critical for it to be understood and appreciated. The introduction of new curriculum on its own can only offer the what of a capstone project. This chapter presented a project description in order to highlight the who, when, where, how, and why of this capstone.

This included the style of curriculum that was created, the framework used to structure it, and the educational reasons for its specific scope and sequence. The way it will be judged and improved on in the future was included to emphasize this project was not a one time act, but a living document to be scrutinized and improved upon in order to achieve long term measurable success for high school physics students.

This capstone started with the hope of answering a complicated career defining question: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* After setting a goal, planning a course of action, and completing a capstone project of new curriculum Chapter 4 serves as a critical reflection of what was learned, what was accomplished, and what lays ahead.

Chapter 4

Critical Reflection

Introduction

This capstone would have turned into something drastically different if done by another person and even if it had been done by me at any other point in my teaching career. The foundational questions and ideas that inspired the topic of this capstone project began ten years ago as I took physics for the first time in high school. That was when I first encountered the stigma many attach to the subject of physics as unnecessary and overly difficult. My interactions with these sentiments grew and evolved as I majored in physics in college and began teaching high school physics. A question that first came to me as I observed a classroom while in college came once again to the forefront of my mind after I completed my second year of teaching. *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* The deep desire to answer that question is what inspired me to write this capstone project. This final chapter serves as a summary of what was created, what it means, and where to go from here.

The work of a capstone project to complete a master's degree is never complete without pitfalls and times of struggle. By sharing the lessons I learned along the way, I hope to help guide future teachers toward success. Arguably, the most daunting task of this type of capstone is the lengthy process of creating a literature review. I highlight the fits and starts I encountered throughout the process to ease the anxiety of future writers and also shed light on the unexpected revelations that can happen. After the slog of reading, evaluating, and synthesizing hundreds of pages of resources, the research eventually serves as a guide to a capstone project that is tailored to answer the original question, structured around relevant literature, and most likely to make a measurable difference on the teaching of a specific subject. This chapter shares the unique way my project formed as well as its implications on the field of physics education and its limitations in being applied as a cure-all. Lastly, this chapter outlines what comes next, both for me as a teacher and for the curriculum I developed.

Lessons Learned

Master's students begin the process of writing their capstone with grand ideas of turning a failing system on its head or developing new and better curriculum, but there are always bumps in the road on the way to that goal. My struggles began as I started to research relevant articles on the way to completing Chapter Two of this capstone, the literature review. Through my college experience as a physics major, I had never done a research project anywhere near the 20-30 pages required for an appropriate literature review. I quickly realized that doing a close reading of every semi-relevant journal article I came across was not going to lead me to success. Countless hours were wasted on articles that I thought might be the best fit I could find, until I would come across two more that made the others irrelevant. My number one research takeaway was to cast a wide net. Reading the abstracts or introductions to more than fifty resources and organizing them into categories is the best way to learn the scope of research available on a given topic. After completing a wide search I was able to hone my focus on a few key topics that continued to appear in a multitude of articles.

The relief of organizing resources and developing a base of research is often unfortunately followed by a sense of loss while staring at a blank page. That was the way I felt as I contemplated how to start a 20-30 page research paper that needed to include citations to 20+ different resources. The idea of just starting to write and going back to edit later with a paper that extensive was so daunting for me that it bordered on ludacris to even consider it. Eventually, through hours of confusion and struggle I learned I needed to outline everything. I broke down my literature review into four main topics and then broke down each of those topics into three subsections. Then I templated exactly where each resource would fit into the subsections and how I would transition from one to the next. The only viable way for me to approach a paper of this size and scale was to outline it with such detail that, when I finally sat down, the paper felt like it was writing itself.

In order to complete this type of writing process I needed to learn how to absorb immense amounts of information from each resource and synthesize it down into an idea that fit perfectly within my paper. The skills required to effectively execute that process were never taught to me. Including direct quotes from dozens of sources is not recommended, so I put in the time to pull out critical portions of each resource and summarize its main findings. Through this process I was confident I could accurately portray the core assertions of all of my resources while using them to tell the story of my literature review.

Revisiting the Literature Review

The process of writing a capstone paper starts with an idea or a question, but when confronted with the eventuality of an in-depth literature review of that topic it is easy to try to force things to fall into place. I found it was tempting to have ideas about where I wanted the topic to go and then try to force the research in that direction. Conducting research in that fashion is untruthful and eventually leads to poor results. After failing to create the connections I had hoped to see, I decided to let the research guide the way to my eventual subtopics. When I took each source at face value and synthesized it through the lens of my own teaching experience and goals, the appropriate path became clear. My hope is for my literature review to serve as a valuable resource for other high school physics teachers who are searching for a breakdown of relevant research and trying to accomplish similar goals in teaching.

Revisiting the Capstone Project

While it did not take long to find the question that would drive my capstone, I did not go into the process with an idea of how to answer it through a final project. Similar to my experience with the literature review, I came to realize the best way to create a project that offers significant value was to allow my findings to guide the way. In my opinion, it was not worth going through the extensive effort of writing a capstone to receive a Master’s unless the research and effort I put in was done in the most genuine and fruitful way possible. This led me to create a final project that was unique in both its scope and sequence.

The overarching goal of my capstone was to find a way to increase the participation and success of struggling students in high school physics courses. My literature review led to two great opportunities in the form of a teaching shift toward problem based learning and inquiry based learning. Both have shown the ability for great student improvement, but interestingly, neither are as effective when implemented as a wholesale curriculum change. This surprising realization led me to abandon the typical capstone project of creating one excellent unit of new curriculum. Instead, I decided the best way to utilize these teaching strategies was to incorporate them in short projects and activities throughout all of the critical physics units as a replacement for the time usually spent on repetitive practice problems.

Implications

While the labs and activities created as a part of my capstone project fit within the current framework of physics education, they also serve to move the physics curriculum in the direction of changes being made at the district and state level within Minnesota. While this capstone was being written, new state science standards were proposed and waiting to be voted on. Among other changes, these new standards put a greater focus on engineering and the ability of students to use the information and knowledge they have mastered to solve real-world problems. The new curriculum I created, especially for the final four topics, models this push for students to use their knowledge to solve more challenging problems.

These new pieces of curriculum also exemplify the type of summative assessment that has been pushed by my district and many others throughout the state. This push is for teachers and schools to shift away from a percentage system that can amplify the damage of any missing assignment (power of zero) and toward clearly defined letter grades based on the standards. This new paradigm asks teachers to think deeply on what it should take for a student to earn an A, B, C, etc. on a summative assignment within each standard. When these criteria are presented to the students they are more easily able to understand what the need to accomplish in order to achieve each grade. The labs and activities I have created are an example of the types of assessments lauded by this new system.

Limitations

The new curriculum presented in this capstone project represents my best effort to match the ideals of problem based learning, inquiry based learning, and culturally responsive teaching strategies while remaining anchored to the reality of the state, district, school, and department I teach within. Balancing aspirations with structure and policy has led to ideas for a new curriculum that has a chance for immediate success when implemented. This work represents my best effort to create a new curriculum with a high level of academic integrity and rigor based on the findings of my literature review and focused on the goal of improving the participation and success of struggling high school physics students. However, it is not a cure-all. It cannot save any and all problems surrounding physics education and it will face roadblocks in implementation, the same as any other new curriculum.

The two most substantial hurdles facing the successful implementation of this new curriculum are a lack of time and, ironically, the dedication of other teachers. There is a limited amount of time within a school year to give students valuable opportunities and experiences. Incorporating new curriculum means something else must be cut. The teacher collaboration required to ensure all students receive the same opportunities within a subject causes new curriculum offered by one teacher to result in the cutting of curriculum by a different teacher. Despite any subtle flaws this old material may have, it has often been cultivated and honed throughout years of teaching. This struggle to push for new and improved ideas is exactly why it is critical to base curriculum proposals on all relevant research. The best chance for success is by presenting new ideas with the notion of improving the learning experience for students and not by trying to force a wholesale change.

Future Steps

The materials created in this capstone project will first be implemented during the 2019-2020 school year. Before the fall semester starts, I will introduce all of these new activities and experiences to the professional learning community (PLC) of job-alike teachers who I work with throughout the year. The new curriculum will be implemented in an introductory physics course with detailed notes taken along the way. It is crucial to monitor the successes and failures of each new addition along the way to ensure that modifications are made to increase effectiveness and positive impact in future years.

The full effect of the implementation of new curriculum based on the ideals found within my literature review will not be felt in full for a number of years. Certain goals surrounding increased understanding and success around a specific concept or topic will be noticed and appreciated in the short term, but those steps are only part of a more long term goal. Piece by piece, I am hoping to reverse the negative stigma placed on the subject of physics by changing the perception of physics classes within my school. The new pieces of curriculum I created will serve as the start of a long journey to not only increase the success of struggling physics students, but also increase student participation in physics courses. It will take years of monitoring the percentage of students who sign up for physics in order to appropriately judge the effectiveness of this goal that serves as the foundation of my career-long aspirations.

Summary

At the outset of my capstone journey, I set out with fervor to answer a question that defined a career-long goal of increasing participation and success of students in high school physics courses. I thought certainly the extensive piece of academic work ahead of me would result in the answers I wanted. Despite months logged in a worthy pursuit of my goal and great research and curriculum developed, I slowly came to realize a truth that should have been obvious from the start: the work is never done. Chapter 4 acknowledged that reality and offered a critical reflection on the entire capstone process. It served as a wide-angle lense through which to see where this work belongs in the broader academic landscape of physics education. The implications and limitations of this capstone project set up a conversation of what comes next in this endless pursuit.

My academic experiences throughout high school, college, and teaching repeatedly set me on a collision course with one overwhelming question: *How can a curriculum be created that will increase the participation and success of struggling students in high school physics courses?* After extensive research into the current reality of high school physics education and the best known teaching strategies to improve the success of students, I came up with a plan to create more interesting, engaging, and challenging curriculum. This capstone project is the result of my best attempt to execute that plan. Regardless of the completion of this capstone, my work will continue. This was the best work I could produce, but I intend to continue to improve as a teacher every year of my career and fight for a better and better answer to the question that has followed me every step of the way.

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