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Science, Technology, Engineering, and Mathematics Education in Chile and the United States

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Abstract

The purpose of this study is to compare the education systems in the United States and Chile. Through an auto-ethnographic lens, the findings compare the way that Science, Technology, Engineering, and Mathematics (STEM) are taught and regarded in each country based on literature review and on personal experience in classrooms in each of these countries. In the United States, STEM education is currently undergoing major reforms; politicians, school board members, teachers, and parents are working to enrich the education this country offers its students. This paper asserts that having an international perspective on STEM education will more fully enhance the current reform movement in the U.S. The Chilean education system is undergoing similar scrutiny, with students demanding that their rights be met. Therefore, it will be informative to compare this movement to that of leaders in STEM education in the United States.

Executive Summary

This study draws on the work of education scholars in the United States and Chile to reflect upon personal experience in secondary Science, Technology, Engineering, and Mathematics (STEM) classrooms and provide a picture of the current and future landscapes of STEM education in the United States. It provides a culturally relevant analysis of current practice of educations and proposes areas for future work in order to enhance the STEM learning experiences of students from all backgrounds. Some of these suggestions include the incorporation of project-based learning techniques, switching from a direct-instruction model to a student-centered classroom, and providing a more equitable education for all students by improving the climates of schools in lower income schools. This project also tackles issues such as gender biases and inaccessibility of certain kinds of learning experiences; these topics are considered important because a major goal of this work is to make STEM more accessible for all kinds of students.

I use the work of scholars such as Diane Ravitch, Linda Darling-Hammond, Seymour Papert, José Joaquín Brunner, and Mario Waissbluth to support the arguments made in this study. Personal lesson plans, samples of student work, and teacher interviews are also included in this project. This multi-media, interdisciplinary study focuses on STEM education on a worldwide scale, and makes claims for the future of students of these subjects. It touches on important and topical themes such as equality in the classroom, differentiation of instruction, and project-based learning within the scope of current literature. This investigation of STEM education will inform future teaching pedagogies and paint a picture of the current landscape of education in two countries for people outside of the field.

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Introduction

Education is an incredibly debated professional field; politicians, administrators, teachers, and parents are viewing the education system in the United States with a critical eye with the hopes of reforming it for the better. However, very few of the so-called top reformists have ever actually taught in a classroom; in fact, many reformers discard the feedback and advice of teachers in favor of think-tank style policy and business-like procedures (Ravitch, 2010). Unfortunately, many of these policies are not helping our current schools; in fact, schools seem to be performing at worse rates than they ever have before. Therefore, many researchers and reformists are looking to international school systems for the answers (Hammond, 2010). The education of Science, Technology, Engineering, and Mathematics (STEM) is in need of particular reform at this time; as a nation, the United States scored in the bottom half in both mathematics and science on the Program in International Student Assessment (PISA) in 2006 (Hammond, 2010).

Through this study, I aim to represent the perspective of the educator in this worldwide reform effort. Based on a more global view and my own experiences in classrooms in the United States and Chile, STEM education should be interactive, student-oriented, and heavily supported by a school's administration in order for teachers to be effective; high-stakes testing and standards, as they exist today, could be limiting not only what educators are allowed to teach, but also how they do so, especially in STEM fields, where creativity and problem-solving are imperative to the success of learners.

This study begins with a review of current scholarly literature in the field of education in the United States. Reviewing the work of Linda Darling-Hammond, Diane Ravitch, and other education scholars, this section is intended to paint a picture of the current policy and rhetoric used in the field of teaching. This section is followed by a literature review of Chilean education scholarship, which aims to show similar aspects of the Chilean education system.

Upon completing a picture of the current landscape of education, I will then provide reflections and systheses of my experiences teaching in both countries. Using the work described in the first two chapters of this study, I will make claims about the future of STEM education based on current reform efforts, policy in both the United States and Chile, and observations and experiences in the field.

The role of the teacher in international education reform is a complex one that deserves a thorough investigation. However, it is also one that requires a reflective and self-evaluative perspective that incorporates data-driven research. In this study, I will take on this perspective and make my own claims about the role of the teacher in the future of STEM education.

Chapter 1: Current Literature in U.S. Education

Based on the current education and policy literature collected for this study, I propose that effective STEM education inspires self-motivated and independent learning on the part of the student (Papert, 1980). Teachers, previously viewed as instructors, should take on the role of facilitator of discussion in this new and more inclusive vision of STEM education. Students will be engaged with the material they are learning as often as possible in order to develop a sense of autonomy over their own learning. Additionally, there needs to be less of an emphasis on testing and standards in favor of a fuller curriculum with student understanding in mind (Ravitch, 2010). All of these changes, many of which have been adopted by school systems across the globe, will lead to a more equitable system in which all students are active participants (Hammond, 2010). According to Linda Darling-Hammond (2010), author of *The Flat World and Education: How America's Commitment to Equity Will Determine our Future*, "… education should develop the richness and diversity of talent for every human being" (Hammond, 2010, p. 177). In the study that follows, I will reflect upon my research and experiences in order to develop incorporate this definition of education into the future of the teaching of STEM.

Self-directed Learning in STEM

Constructivism, credited mostly to Seymour Papert (1980), suggests that learners should be agents of their own acquisition of information. More specifically, students are capable of building upon the knowledge they already have through exploration, independent study, and play in order to create tangible and understandable ideas (Papert, 1980). In order to achieve this goal, children move through Jean Piaget's stages of development, although perhaps not as linearly as Piaget argued: sensorimotor thought, preoperational though, concrete operational thought, and formal operational thought. In all of these stages, the use of the five senses is absolutely imperative (Cook, 2005).

Piaget also argued that learners are incredibly influenced by the environments in which they are developing (Cook, 2005). Papert used this idea as the basis of his ideology for STEM education. In his book *Mindstorms: Children, Computers, and Powerful Ideas,* Papert discussed the fundamental errors in the way we teach mathematics and technology. Unlike in other fields, such as English and history, students are not exposed to the language used in STEM fields until much later in their lives; therefore, they have no knowledge on which to base their learning, which sets them up for misunderstandings (Papert, 1980). While they are expected to be in the final stages of Piaget's development model, they in fact are only just beginning to develop as learners of mathematics and technology. In order to bridge this gap, Papert suggested fundamental changes in the way educators approach the teaching of mathematics.

In *Mindstorms,* he presented the idea of "Mathland," a space in which learners grow in order to better understand mathematics at a higher level. In "Mathland," students would be introduced to games and language that incorporate mathematics at a much younger age. In reality, this technique is not much different than the ones used in other disciplines.

> Imagine that children were forced to spend an hour a day drawing dance steps on squared paper and had to pass tests in these "dance facts" before they were allowed to dance physically. Would we not expect the world to be full of "dancophobes"? Would we say that those who made it to the dance floor and music had the greatest "aptitude for dance'? In my view, it is no more appropriate to draw conclusions about mathematical aptitude from children's unwillingness to spend many hundreds of hours doing sums. (Papert, 1980, p. 43)

This analogy between the teaching of mathematics and the teaching of dance demonstrates the need for mathematics education to be more hands-on and interactive from the beginning;

students should not need to learn formulas by rote memorization before they are exposed to their applications.

Goals of STEM Education

The goals of a STEM classroom go far beyond the content that students will be learning. Students must be fluent in the subject they are learning, which has different implications depending on the content. The strands of mathematical proficiency, written about by Jeremey Kilpatrick, Jane Swafford, and Bradford Findell (2001), are guidelines that can be applied to any STEM classroom, not just within mathematics. In their book, *Adding It Up: Helping Children Learn Mathematics*, these strands are conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (Kilpatrick, Swafford & Findell, 2001). According to these education scholars, all five strands need to be incorporated into every student's mathematics education in order to ensure a full and deep understanding of the content. They define these strands in clear and concise ways so that they can be easily implemented in any STEM classroom.

Conceptual understanding is defined as the ways in which a student understands the content being taught, including "concepts, operations, and relations" (Kilpatrick et al., 2001, p.116). Similarly, procedural fluency is the confidence with which students can perform procedures to a certain degree of accuracy. A student's "ability to formulate, represent, and solve mathematical problems" is what these authors would consider his or her strategic competence (Kilpatrick, 2001, p.116). However, the final two strands of this model are slightly less traditional. Adaptive reasoning consists of the ways in which students make their thought processes clear to others, and the ways in which they formulate logical thoughts and arguments. This strand also incorporates the ideas of justification and explanation. Finally, productive disposition is the "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (Kilpatrick, 2001, p. 116).

The importance of explanation and justification are particularly important in a STEM classroom, and, unfortunately, these skills that are often overlooked by educators. Through my time spent observing and working in secondary schools, it is clear that much of the focus is on the second strand, procedural flunecy; students are given the rules and tools necessary to complete problems, but they are rarely given the opportunity to truly understand these concepts, nor are they asked to explain them. However, it is important to ask that students justify their responses, and to encourage them to engage in discussions with their peers about what they are learning. These kinds of discussions will encourage students to understand the different ways in which problems can be approached, and it will also disprove the common misunderstanding that in STEM, there is a single correct answer.

A result of these strands of mathematical proficiency was the development of the mathematical practices as part of the Common Core State Standards – Mathematics (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). These practices also ask more of mathematics students than correct answers and procedural fluency, and again, can be applied to all of the STEM fields. These eight practices expect that students can understand the desired outcome of problems, use the correct tools and procedures based on repeated reasoning, and develop mathematical models and representations. Students are also expected to construct precise and legitimate arguments, while developing the ability to critique the logic of others. A student proficient in the mathematical practices can look at a problem, use its structure to understand it, apply the appropriate concepts, and defend the resulting solution (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010).

These guidelines for teachers, which are now supposed to be implemented in New York state public schools and in many other states, encourage a deeper understanding of content. They expand upon the original strands of mathematics to create a more holistic and relatable context in which students can learn. It is through these practices that students can begin to understand the importance and applicability of STEM education. Three of these practices address the construction of arguments, the use of structure, and the importance of reasoning. These practices help students to develop problem-solving skills that can be used in a variety of settings outside of the STEM classroom (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010).

The Effects of Standardization and High Stakes Testing on STEM Education

Diane Ravitch, former Secretary of Education in the United States, wrote the book *The Death and Life of the Great American School System: How Testing and Choice Are Undermining Education* (2010) as an answer to the push for nationwide standards and accountability based on testing. In this piece, she discussed a variety of topics as they relate to the future of education in the United States. Most poignantly, she discussed the evolution of the standardization movement over the past several decades. At the beginning of this movement, Ravitch was an avid supporter, suggesting that all states needed to be held to the same standards in order for equitable education to be achieved. However, as the push for a common set of standards became stronger, it slowly transitioned into a push for standardized testing (Ravitch, 2010).

The standardization movement began in 2002 with George W. Bush's *No Child Left Behind* program (NCLB) (Ravitch, 2010). The intention of this program was to eliminate the achievement gap in the United States through stricter forms of accountability for teachers. However, the result was far from an advancement, according to Ravitch. NCLB set unrealistic goals for public school teachers, proposing that every student would be proficient in mathematics and English by 2014 under its guidelines. However, this expectation set extreme limitations on what students were learning in schools, and especially on how they were demonstrating that learning. Because NCLB required that funding be cut from schools that did not meet the standards set forth in its guidelines, schools were hyper-focused on the instruction of mathematics and English. In fact, in some school districts, generally those in danger of being closed, all other instruction was ceased for the month leading up to state examinations (Ravitch, 2010). Therefore, the students were taught to pass tests, rather than to truly learn and understand new content. As Diane Ravitch stated in her book,

> No Child Left Behind … was bereft of any educational ideas. It was a technocratic approach to school reform that measured "success" only in relation to standardized test scores in two skill-based subjects, with the expectation that this limited training would strengthen our nation's economic competitiveness with other nations. (Ravitch, 2010, p. 29)

Essentially, according to her work and investigation, NCLB turned the standardization movement into a testing movement, and in doing so, played a huge role in the decline of the education system in the United States.

NCLB is in direct contrast with the vision of STEM education put forth by constructivists and current education scholars; students are not allowed to build their own knowledge and understanding when their teachers are held to such strict standards. However, Ravitch also pointed out the dangers of constructivism in its purest form; she argued that schools that adopt any single method of teaching or curriculum are bound to limit the learning of their students. In this section of her book, she discussed a public school in New York where the administrators adopted a completely constructivist curriculum. In this school, the teachers were told what they could teach and how they could teach it, in addition to being restricted from using textbooks and certain instructional materials (Ravitch, 2010, p. 41). While the ideology behind constructivism is strong with respect to the learning of STEM, any programs that restrict the way that teachers instruct will have negative effects on the educational experiences of the students.

Linda Darling-Hammond addressed these issues of restrictions in her book *The Flat World and Education: How America's Commitment to Equity Will Determine our Future* (2010). In this book, she discussed education reform on a worldwide scale, and compared the changes being made in the United States with the ones being made in countries with more successful school systems. When it comes to teachers, she recognized that not only are educators held in higher regard in other countries than they are in the United States, but they are also given more support during their careers. In Singapore, for example, teachers receive up to one hundred hours of teacher development, paid in full by the state, and they are given twenty hours a week to collaborate with the other teachers in their schools (Hammond, 2010, p.190). New teachers in Korea are a part of a six-month program in which they receive support from their administration and veteran teachers in areas such as classroom guidance and supervision (Hammond, 2010, p.180). Both of these nations performed at the bottom of international assessments in years past, but have quickly shot to the top. Darling-Hammond argued that the United States should take note of these changes in order to create a more effective education system.

Darling-Hammond also pointed out the ways in which STEM is taught differently in these countries that have undergone successful reforms. In today's educational rhetoric, Singapore is regarded as on of the most innovative countries with respect to the ways in which STEM is taught. Mathematics and science classrooms in Singapore are interactive, student-oriented, and related to real-world problems. This kind of teaching is the trend in many countries other than the United States.

> As in Japan and Hong-Kong, China, math students frequently work in pairs or small groups on problems contextualized in the real-world, come to the board to explain their answers, and question one another about their findings and conjectures, creating a strong mathematical discourse that supports understanding. (Hammond, 2010, p. 185)

In reality, this so-called innovative approach to teaching STEM resembles the vision of Papert, and is also reflected in the mathematical practices adopted by many schools in the United States. However, administrators in most public schools do not make these practices a priority; rather, they are focused on standardization and accountability. Therefore, even though teachers are given the tools to teach STEM in a more interactive way, they are restricted from doing so.

Chapter 2: Current Literature in Chilean Eduaction

The recent history of Chile is a dark and twisted one, with a long period of dictatorship between 1973 and 1990 in which Augustus Pinochet committed an innumerable amount of violations of human rights. This period of time, which was not all that long ago, is being erased from Chilean history; it is seldom discussed, students are not taught about this era in school, and families of the victims have very few spaces in which they can speak about their feelings. However, despite this attempt by the government to cover up such a disastrous period, the effects of this military reign are ever-present in the Chilean society. School systems have been run very differently since the regime of Pinochet, and the middle and lower classes are suffering for it. Some of the main themes of Chilean education literature in today's academia are the privatization of schooling, inequity and restriction, and a movement of students calling for change. Many of these topics are heavily discussed in the field of education in the United States, which makes for an important comparison between the two countries.

The Creation and Emphasis of Private Education

Before the dictatorship of Pinochet, a majority of schools in Chile were public; in fact, the best schools in the nation were public schools, which allowed a majority of students to receive a quality education. However, the regime of Pinochet was incredibly militarized, and adopted a business model within the education system. Chilean students were, and still are, viewed as clients and consumers of a product. Therefore, the goal of the education system is to provide the desired service for as little cost as possible, in order to maximize profit (Brunner, 2014). With this goal in mind, more private K-12 schools were created. These schools served an incredibly small population of students: the upper class. With high tuition rates, students who came from families with lower incomes were excluded from these new, elite educative spaces (Brunner, 2014).

As private schools began to get more support from the government, they became more competitive. Students in Chile are required to take a standardized test during their high school years entitled La Prueba de Selección Universitaria (PSU) in order to matriculate to a university. The PSU is very similar to the SAT in the United States, with a verbal and mathematical section. However, this exam also focuses on history, science, and social studies. As the business model for education took off in Chile, students from private schools started scoring higher than their public education peers on the PSU. As the scores at these schools began to rise, they became even more popular amongst the families of the upper class, and these schools began to educate more students (Wirth, 2014).

Unfortunately, Chilean schools operate under a system in which funding is awarded based on the number of students enrolled in the school. Due to the swell of popularity amongst private schools, public high schools inherently have fewer students. Therefore, these schools, which were already struggling during the reign of Pinochet, receive significantly less funding than their private counterparts (Wirth, 2014). This discrepancy in funding further widens the gap between public and private schools, making private schools more desirable and public schools less prepared to properly educate their students.

Ironically, private universities are not nearly as competitive or prestigious as the private K-12 schools in Chile. In fact, public universities are the ones with the highest number of students enrolling currently, while private schools, which are not required to be accredited, are generally viewed as the catch-all institutions for students who were not accepted to a state university. This difference in attitude in K-12 schools and higher education creates an interesting dynamic amongst Chilean students. Due to the lack of funding received by public schools, students who attended these institutions are significantly less qualified than students from prestigious private high schools. Therefore, those students who could not afford a private education in high school are more often accepted only into private universities, which are more expensive than the state-funded public institutions. Once again, students of public K-12 schools are put at a disadvantage; they are less likely to get into a school in which they will receive a quality education, and to make matters worse, they will have to pay more for the lower quality education (Brunner, 2014).

Currently, José Joaquín Brunner (2013), one of the leaders in Chilean education reform, has called for the organization of public education. Because there is no consistency or leadership amongst public Chilean schools, according to Brunner, those students suffer. When the students in these schools are not given a structured education, and when their administration is not organized enough to take on the neighboring private schools, it is difficult for them to be successful and competitive. Brunner argued that, instead of allowing local mayors to have complete control over their school districts, there should be a board of officials who oversee public schools in general in Chile. These officials would help make curriculum decisions, as well as help structure public schools in order to provide a stronger educative experience for their students (Brunner, 2013).

Brunner’s push for organization is in direct response to the privatization of Chilean schooling; private schools developed their strength and monopoly on education through support from the government in the form of leadership and organization. If public schools could mimic this trend, they might be able to begin to provide their students with better education opportunities. Interestingly, the reforms proposed by Brunner almost exactly mirror those made in the United States over the past few decades. There has been a major push in this country to standardize education and make it more consistent. While there are downfalls to this approach, as demonstrated in the work of Darling-Hammond and Ravitch, there are many positive effects of having an organized and consistent education system. Especially in a system as broken and divided as that of Chile, it is important to incorporate some structure in order to provide students with a more consistent and comprehensive education.

The Effects of a Broken System: Inequity and Restriction

The culture of Chile is currently one of inequality and classism; there is an incredible divide between those of the upper class and those of the lower class. This culture has extended itself into the schools of Chile, creating an achievement gap between students of different socioeconomic backgrounds. After schooling became privatized, students from families with less money were not able to afford the better schools. For that reason, many students from lower socioeconomic situations receive poorer educations than their upper class peers (Waissbluth, 2014).

Scholars such as Brunner have also identified the main factors to Chilean students' success. They recognize home and family life, school community, and the institutional aspects of each school as major influences over a student's learning. They suggest that family interactions are important in the development of motivation and cognitive processes of young children. Unfortunately, students of lower socioeconomic classes receive less of this vital interaction, as many of their family members work long hours at multiple jobs (Brunner, 2014). This lack of communication within the home puts students from these families at a disadvantage in school.

Brunner and his colleagues have also identified class environment, the strategy of teachers, and use of class time as important factors in the success of students in Chile. According to Brunner, students with less qualified teachers are less likely to achieve the same level of accomplishments as students who learn from well-trained teachers (Brunner, 2014). Generally, schools in lower income areas cannot afford to hire the best teachers with the most comprehensive education. This lack of trained teachers is yet another way that students who attend public schools in lower-income areas are put at a disadvantage in the Chilean school system.

Tracking is also a significant problem in Chile, as it is in the United States. Tracking is a system in which students are placed in a specific class early in their educational careers, and they are then set to take a regimented series of courses as they continue through the education system. It is very difficult for students to switch tracks during their time in schools, which means that students who test into lower classes early on will be stuck in those classes for the duration of their high school experience, regardless of growth or academic changes. To many Chilean theorists, tracking is a form of segregation within schools. As students from lower socioeconomic classes are less prepared for tests than their peers from wealthier backgrounds, most of these students place into the lower level courses, or in some cases, the less qualified schools. This practice of separating students from different socioeconomic classes further widens the achievement gap between students of the upper and lower class ("Derecho a la Educación…", 2014).

These attitudes and discrepancies promoted in schools mirror those of Chilean society as a whole. During the dictatorship of Pinochet, a great sense of classism fell over the country, with people of the upper class feeling more entitled to basic human rights than the lower class citizens. When students who come from families from lower socioeconomic classes are placed in lower level courses and at poorer performing schools, this sense of superiority is promoted.

Additionally, it further promotes the sense of importance of the individual over society at large; during the time of Pinochet's rule, a very small group of people benefitted while most of the country suffered. This disparity can be seen within the public and private schools of Chile as well (Waissbluth, 2014).

Censorship and restriction were also forms of control that were enforced during the Chilean dictatorship; media was closely monitored, and citizens could find themselves in jail simply for speaking about a forbidden topic in the wrong place. This censorship found its way into the classroom as well. Creative opportunities were all but eliminated from Chilean schools, with a focus on traditional methods of rote memorization and test taking. Additionally, the subjects that were taught were strictly limited by the government, and continue to be to this day (Waissbluth, 2014). For example, students in high schools, both public and private, are not allowed to learn about the dictatorship in any amount of detail. Other than the name of the leader, the students are not taught any content about this period of time in their classrooms. This restriction of both teaching methods and content greatly affects the ways in which students learn.

Because of all of these restrictions in Chilean schools, the students are being greatly affected in their ability to perform certain tasks. On the Programme for International Student Assessment (PISA), an exam administered worldwide in order to assess the progress of a variety of students, 50% of Chilean students score below proficient in mathematics, and 30% score below proficient on the oral section (Brunner, 2014). Additionally, studies have shown that students from schools in Chile lack skills in inference, relating concepts, and problem solving. Additionally, they struggle to think about larger scale ideas, they lack the ability to properly utilize formulas, and they are not proficient at representing information visually (Brunner, 2014). Many of these disparities come from the differences in funding received by the variety of types of schools; some of the areas for growth of Chilean students have also been linked to the restriction of the information allowed in schools since the reign of Pinochet. Regardless of the cause, many education scholars are currently looking to close these gaps, both academic and non-academic, in order to create a more equitable education experience.

Many scholars in education argue that the disadvantageous position of students of lower socioeconomic classes should be considered a violation of human rights. Especially because there were so many of these violations taking place during the dictatorship of Pinochet, those committed within school systems should not be forgotten (Waissbluth, 2014). Students of certain demographic backgrounds were denied the same opportunities as those of their peers that had been hand selected by the government; as many Chileans consider education a right that should be afforded every student, this violation should be taken seriously. The relationship between the dictatorship and Chilean education is a complicated one in which the lines of cause and effect are greatly blurred; however, the significance of the achievement gap in this country should not be taken lightly.

A Call for Change: The Student Movement in Chile

While there are many negative systematic aspects of the Chilean education system, its students provide a prime example of young people taking advantage of their rights and demanding what is rightfully theirs. Only recently, Chilean students have taken to the streets, calling for changes in their schools. These changes include demands for an equal, free and inclusive education (Wirth, 2014). In other words, students want school in Chile to be available to all students, regardless of their demographic background, free of charge.

The Chilean student movement is felt very strongly within Chilean culture. It has taken the form of protests, marches, and demonstrations in the streets (Wirth, 2014). The students are taking advantage of their right to speak their minds publically, a right that many students were not able to act upon in the decades before. The students in Chile feel very passionately about their educational rights, and students all over the world should replicate this passion. While they may be fighting against a long-broken and traditional system, they are fighting it with great force, and this climate of unrest is very evident in Chilean schools.

There are also many calls for reform within the selection process of students for a university education. Currently, the same achievement gap that exists in secondary schools is reproduced in higher education, with students from higher socioeconomic classes being accepted at higher rates to the best programs at the most prestigious schools (Brunner, 2013). Reformists, such as Diego Vela in Chile, are calling for more transparency in university selection so that students can be more aware of the requirements to enter a program before they apply. Additionally, Vela suggests that major universities adopt a more holistic approach when selecting their students; this approach would require them to move away from test scores and assess student qualities that are not encompassed within these exams (Brunner, 2013). While these kinds of selection criteria are more difficult to assess, university programs will be greatly enhanced with the enrollment of a wider variety of students.

While the education system of Chile has undergone a very different series of events than that of the United States, the problems suffered by its respective students are very similar. Achievement gaps and inequity in schooling are problems that exist in both school systems, and the adoption of a business model has taken over both methods of schooling. One of the main differences between these two countries is the activism of the students. Chilean students are very focused on causing change in their schools, and they are working endlessly to have their demands met. Students in the United States, on the other hand, tend to be more complicit within their system. There are lessons to be learned from both of these education systems, and reflecting upon the way students are taught and regarded in both countries will help enhance the learning experience of all.

Chapter 3: Chilean Teaching and Learning Experience

While studying abroad for a semester in Santiago, Chile, I had the opportunity not only to take classes taught in Spanish, but also to teach English at an all boys public school in the city. Both of these experiences helped me to draw a clearer picture of the education system in Chile, and they were also incredibly formative in my development as a future educator. Learning in a different language allowed me not only to develop a deeper cultural understanding, but it also helped me become more sensitive to the needs of language learners in the classroom. Obviously, teaching English to a group of native Spanish-speakers allowed me to develop techniques for teaching language learners as well. All of these experiences aided me in reflecting upon my methods of teaching, the ways in which language learners best comprehend content, and the important effects of cultural exchange in a classroom.

Teaching in a New Language: A Challenging Experience

Prior to my position at Liceo Andrés Bello in the neighborhood of San Miguel, I had never taught English before. I was excited at the chance to expand my horizons and try a new form of teaching, but I was nervous that I would not meet the needs of my students. I was given the task of improving the students' speaking and oral comprehension skills. Therefore, conversation was a huge part of the time I spent with my students in class.

The students were preparing for the Key English Exam (KET), which is an exam that assesses the English language skills of Chilean students. The director of the program at this school asked me to focus on the listening and speaking sections of this test. On these sections, students are asked to answer questions about spoken conversation. These questions take the form of short answer responses, matching questions, multiple choice problems, and fill-in-the blank exercises. Students are also asked to orally conduct a mock interview and to have a conversation with a partner based on suggested questions (Exam English, n.d.).

Based on these exam requirements, I chose to incorporate conversation into our weekly routine. Each class, I would present the students with a topic of discussion, such as stereotypes, music, or Chilean history. After being given time to brainstorm ideas about this subject, the students would be asked to engage in a group discussion with one another; each student was required to speak at least once, forming a complete English sentence. At first, these discussions were slow and required a lot of guidance, as reflected in this excerpt from my journal on September 28, 2014:

> The discussion went really well. At first, they were nervous to say some of the stereotypes about the U.S. However, once I showed them that I could laugh at the stereotypes, they opened up. Again, I have to think of ways to get the quieter students to speak up during these conversations. Hopefully, as we do more small-group activities, they will become more confident in speaking in the large group.

Indeed, the students showed much progress over the course of the semester. By the end of our time together, they were completely comfortable taking part in these kinds of discussions, speaking their minds and sharing their opinions with me and their classmates. The structured nature of these conversations, in combination with the relatable topics chosen and the informal atmosphere of our classroom, allowed the students to develop their confidence speaking in a language that was not their native tongue.

Of the variety of topics selected for these group discussions, the students opened up most readily during the lesson focusing on music. Within my first few weeks of teaching, I learned that many of the boys in my class had a real passion for music, and many of them played instruments. So, I planned an entire class around the topic of music. This incorporation of their preferences and interests made it much easier to help the students feel comfortable speaking in class, as evident in this reflection from October 10, 2014:

> The boys loved the lesson about music. It was so much easier to get them talking about a subject in which they are interested. They were excited to share their opinions on different types of music, and it was much easier to get the conversation going this week.

Working discussions into our weekly lessons allowed me to fortify my understanding of the importance of incorporating the personalities and interests of my students into my lesson plans.

When participating in these discussions with my students, I had to become more aware of my style of speaking than I ever had before. I made a serious effort to focus on my speaking speed, to eliminate vocabulary that was beyond the scope of their language comprehension, and to eliminate slang and colloquialisms from my speech, instructional choices supported by Murrey (2008). This focus and self-reflection proved to be a very difficult task; never before had I thought too deeply about my patterns of speech, but I quickly learned that my speaking style greatly affected the ways in which my students learned. As I have grown as an educator, I have learned this to be true not only in language learning settings, but in all educative situations. Students are greatly affected by the language of their teachers, as evident in the work of Herbel-Eisenmann (2002), who demonstrates the process of language acquisition of all students in STEM classrooms. Teaching in Santiago allowed me to deepen my self-awareness in a positive way that will greatly affect the ways that all of my future students, not only language learners, will learn in my classroom.

Learning in Non-Native Languages

When I decided to study abroad in Chile, the aspect that made me the most nervous was the prospect of taking all of my classes in Spanish. While I felt that I was fairly proficient in Spanish, the idea of learning alongside native speakers made me uneasy. Especially since these classes were not language classes, and rather regular content courses taught at the university, I knew that there would not be a focus on language learning; in fact, I was well aware that I would likely be left to my own devices when it came to understanding, writing, and speaking Spanish in class. While this experience was incredibly difficult, it also better prepared me to understand the needs of my students.

Nikula and Nelson (2014) have conducted much research that supports the incorporation of content and language learning for students learning English. The opportunities for students to contextualize new vocabulary allow for faster and deeper language acquisition on the part of the students (Nikula & Nelson, 2014). As a language learner in a new country, I certainly found these theories to be true. While I was still learning how to speak more fluently and understand the language of those around me, I was taking a course in Latin American art and another in detective literature. Both of these classes required a significant amount of reading and a content-specific vocabulary. Had I been asked to memorize and understand the words necessary to describe detective literature in Spanish without context, I would have struggled; however, learning them while reading material, attending lectures, and writing essays was a far more natural process. Similarly, learning terms used in the field of visual arts was not as difficult as I would have anticipated as they were all contextualized as they were introduced.

This realization of the importance of context in language acquisition will have many benefits on my future instructional decisions. Clearly, I am more aware of the needs of language learners within a mathematical classroom; should I teach in an area with a concentrated population of language learners, I will be better prepared to support them in my classroom. I will be able to contextualize language for them in order to make it easier to understand, but I will also be aware of the struggles present in learning a language while taking grade-level courses.

Therefore, I will make similar accommodations as those that I was given while in Santiago, which include teacher-support, the use of a translator for written assignments, and, when necessary, a modified rubric for written or oral assignments.

However, the learning of mathematics is similar to the learning of a new language in general. Students of all backgrounds are asked to learn new vocabulary words, to speak in structured and different ways, and to explain their ideas within a specific content. Therefore, these same accommodations and understandings in place for language learners in my future classroom will help all of my students develop a stronger use of academic language. As Herbel-Eisenmann (2002) recognized, the use of classroom language is important in the understanding of mathematics; the appropriate scaffolds need to be put in place in order for all students, not just language learners, to learn how to speak about mathematics in a technical and accurate way. My experience teaching and learning within a different culture has prepared me to teach all of my future students, but especially the language learners in my classrooms.

The Importance of Cultural Exchange

The most important take away from my teaching and learning experiences in Santiago, Chile was the value of experiencing and understanding a culture different than one's own. While the classes I took in Chile were very informative and interesting educational experiences, I often argue that I learned the most from simply living in a foreign country. This semester abroad was absolutely critical in my development as an educator; having spent time abroad, I am more sensitive to cultural issues, and I can relate to the struggle of assimilating to a new culture while growing as a learner.

Within the context of teaching, I have always understood that it is important to relate the material to the cultural experiences of the students. However, I had never appreciated the value of this practice as fully as I do having taught in a foreign classroom. The lessons in which my students were most engaged and learned the most, and in which I felt most fulfilled, were the ones that allowed us to share in aspects of one another's culture. Most often, this exchange took place during the large group discussions we had in class each week. The lesson surrounding music is a strong example of the power of this cultural exchange.

In this music-centered lesson, our large group discussion was focused on different styles of music. The students talked about their musical preferences, the importance of lyrics, and the ways in which music affected their daily lives. After talking with the students about their favorite music, I shared with them my own, playing three songs for them. As they listened to these selections, they were asked to listen carefully to the words in order to describe what they thought the songs meant. While it took several repetitions of each song for the students to truly understand them, each student understood the songs and their meanings by the end of class.

As it turned out, this lesson was one of the most successful of all those executed during my time teaching at this school. The students were most engaged in it as it was based on one of their common interests. However, they were also excited to hear popular music from the United States, and in listening to my music, they got to know me on a more personal level. The importance of this exchange is outlined in my journal entry from October 10, 2014:

> Sharing my own music with them proved to be a good technique as well. They had not heard most of the songs, and they did an excellent job understanding the lyrics. I am always impressed with how well they navigate the lessons I plan each week.

Clearly, the personal connections I made with my students in this lesson allowed them deeper access to the material in order to develop stronger speaking and listening skills.

Working so closely with Chilean high school students allowed me to better understand the country in which I was living as well. One of the most powerful examples of this understanding came from the day that we discussed the period of time during which Pinochet was the leader of Chile. In order not to cross any boundaries set forth by the school in which I was working, I simply asked the students to tell me all that they knew about the years between 1973 and 1990. Shockingly, they knew very little. They wrote about the curfew, that Augustus Pinochet was president, and that Los Prisioneros, a famous rock group formed at their high school, made most of their music during that time period. It was shocking to see the way that this period of time had been almost completely erased from history, with an entire generation of people knowing almost nothing of these years.

As the conversation continued, the boys expressed a great interest in learning about this period of time. They talked about they ways in which their families avoided talking about it, and how they were always curious about what went on during those years. It was very clear to me that the students were aware that it was a dark period of history for Chile; they knew that terrible acts went on during those years, but they wanted to know the effects. Most strikingly, the students expressed the importance of learning history, as described in the following journal entry from November 7, 2014:

> They expressed a desire to learn more, especially about how the dictatorship affected their own families. They also think it is important to learn about your country's history, even though they do not always enjoy doing so, because then you can learn from the mistakes of the past. They also said that if you know what happened in the past, you can see if society is heading towards a similar situation.

While it was difficult to see the way that these students struggled with the very little understanding they had of their own country's history, I was so impressed at the profound and mature way they handled themselves in this conversation. The students understood the importance of what they were not learning, and had a desire to learn unmatched by other students with whom I had worked in the past. The level of student engagement in this lesson reflects how seriously the students took this material, and this kind of cultural understanding is exactly what I hope to re-create in my future classroom, wherever that may be.

When I volunteered to teach English at a local school, I had no idea the effects it would have on my perspectives on education. However, the deep appreciation of cultural exchange and personal connections that I formed through this experience will only help to enhance the learning of my future students. While this teaching experience may not have been in a STEM classroom, it taught me invaluable lessons in the importance of making connections, being aware of the needs of my students, and teaching in a variety of ways to accommodate all kinds of learners.

Chapter 4: Benefits of Project-Based Learning in STEM Education

The connections between secondary STEM education and engineering education at the university level are often overlooked when discussing education reform. Certainly, I was unaware of the complicated relationship these two fields share. Much of the work done by engineers and engineering students is based in mathematics courses such as differential equations and linear algebra; however, the current landscape of engineering education very closely mirrors the discourse surrounding the changes that need to be made in mathematics and science classrooms at the K-12 level. These similarities were highlighted for me during my summer spent conducting research at Olin College of Engineering. During my time at this school, I worked on a research team comprised of an engineering design student and a mechanical engineering student. Our mentor was a professor at Olin College in the field of computing and innovation. Under his guidance, we studied the effects of project-based learning, namely Rube Goldberg machines, on secondary STEM classrooms.

Olin is considered by many to be one of the most innovative engineering programs in the United States. This school, which offers only engineering degrees to its students, has a heavy focus on project-based learning experiences. Almost all of its classes are team-oriented and student-centered, allowing the students to work very closely with the material. Olin's mission statement reflects this emphasis on the students' learning experiences:

> Olin College prepares students to become exemplary engineering innovators who recognize needs, design solutions and engage in creative enterprises for the good of the world. Olin is dedicated to continual discovery and development of effective learning approaches and environments, and to co-developing educational transformation with collaborators around the globe. (Vision and Mission, n.d.)

Clearly, I was situated in exactly the right kind of environment to conduct my study on project-based learning. However, the context in which I was working was also incredibly formative in developing my understanding of an ideal STEM educational experience.

While surrounded by students afforded an education experience entirely different than the that of typical engineering programs, I was studying a variety of different kinds of project-based learning, a term that has become a catch-all for every kind of learning environment that is not direct instruction. This environment was conducive to my work, as I saw examples of current literature in engineering education scholarship on a daily basis. However, working so closely with students who learned in this hands-on way affected the ways I think about STEM education in ways I never could have foreseen.

The Relationship Between Engineering Education and Secondary STEM Education

Having taken introductory level mathematics courses with engineering students during my first two years at Syracuse University, I was well aware that mathematics and engineering were closely related; I understood that much of the technical work done within the field of engineering was based on computational mathematics. However, I was completely unaware of the similarities in learning styles between students of these two dispositions. Students of mathematics are inherent problem solvers; especially in higher-level mathematics courses, students are not asked for the solution of the problem, but rather the steps taken to arrive there. A huge part of a student's mathematical career is learning how to approach problems in creative ways. In fact, this aspect of mathematics education is so important that it is one of the eight Standards for Mathematical Practice set forth by the Common Core. Standard CCSS.Math.Practice.MP1, "Make sense of problems and persevere in solving them" states that:

> Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution… They make conjectures about the

> form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt… they continually ask themselves "Does this make sense?" (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010)

This process of arriving at a solution is an incredibly important skill for prospective engineers. When in the field, engineers are constantly faced with problems in need of solving; their job is to find the most efficient route to solving those problems, thinking creatively and abstractly at times. At Olin, there is a major focus on this kind of holistic education that allows students to better approach problems in the field. Some of the major themes of the curriculum at Olin include:

> … interdisciplinary and integrated teaching, hands-on learning and research opportunities for students, improved communication skills, students working as members of teams (the way that engineers in industry work), exposure to other cultures or an international experience, and a better understanding of business and management practices. (Statement of Founding Precepts …, n.d.)

The problem-solving skills developed in secondary mathematics classrooms allow students to thrive in this kind of environment, and set them up to more effectively complete the tasks associated with their fields. The importance of problem solving in a mathematics class was not clear to me until I saw its prevalence in a real-world context.

However, despite this commitment to innovation at Olin, as-needed mathematics curriculum has been developed in which students learn only the procedures from calculus and linear algebra that apply directly to their field of interest. Students are required to take two courses under the title of "Linearity;" all other mathematics courses offered at this small college are elective in nature. In Linearity I-II, students learn the basics of linear algebra and differential equations as they pertain to the field of engineering. Most of the focus is on applications of these processes and procedures (MTH2210, n.d.). Therefore, students develop a strong procedural fluency, but they lack a deeper conceptual understanding of mathematics; they are not proficient in many of the problem-solving techniques that come from taking a proof-based course.

Per the Common Core State Standards, mathematics teaches its students to reason in abstract ways, attend to precision, and make use of structure. These ways of thinking translate to many fields of study, but they are particularly important within the context of engineering. As a future teacher of students who may be interested in these kinds of technical fields, it is incredibly important to be cognizant of this relationship within STEM fields and to reflect upon how my teaching may relate to my students' higher educational experiences.

Applying Project-Based Learning to Secondary STEM Education

While the mere experience of studying at Olin College allowed me to understand the importance of project-based learning, these teaching techniques were also the focus of my research. After collecting much data from constructivist theorists such as Seymor Papert and Sherry Turkle, my research team settled upon the topic of Rube Goldberg machines for the focus of our study. We argued that these machines, defined as multi-event contraptions designed to accomplish a single, simple task, were one of the most effective tools in preparing students to be creative problem solvers. Within the context of this study, we also defined an innovative mindset, characterized by creativity and adaptability in the invention of new ideas. This way of processing also allows its thinkers to engage in iterative failure without a feeling of discomfort. Rube Goldberg machines, we argued, are the most accessible and inclusive way to achieve these learning goals within a classroom.

While these chain reaction machines were the main focus of our study, the work that we did to lead to this subject was incredibly informative to the ways that I think about my future teaching practices. I was particularly interested in the accessibility of different kinds of project-based learning to a variety of learners. Therefore, I studied the FIRST Robotics program, creative digital media projects, and gender biases within STEM spaces. The focus of my work within these contexts was on the ways they included or excluded certain students from higher-order thinking experiences.

The inaccessibility of project-based STEM learning. FIRST Robotics Competition is a well-known robotics program that challenges students to find creative solutions to complex problems while learning the technical skills behind building robots. For Inspiration and Recognition of Science and Technology (FIRST) has expanded from a robotics competition to a series of programs, including a Lego league, technology challenge, and a school-level junior program (FIRST, n.d.). Studies have shown that this program helps its participants develop an interest in technology and science, and also helps them to build their problem-solving skills (FIRST, n.d.).

My focus on the development of mathematical reasoning and problem solving led me to believe that FIRST Robotics was the answer to all of my teaching questions. However, as I began to research the program further, I discovered a road block that forced me to reconsider this conclusion: the cost of the competition. The fee alone for the FIRST Robotics Competition, the most popular and hands-on of its programs, is $6,000 per team. This figure does not include the materials and coaching necessary to be successful, nor does it include travel fees (FIRST, n.d.). Obviously, FIRST serves a very small population of learners, excluding many simply for monetary reasons.

Having rejected FIRST robotics as the ideal project-based learning scenario, I began to investigate other methods of project-based instruction. I was drawn to the work of Dr. Sugata Mitra, the founder of Self-Organized Learning Environments. (School in the Cloud, n.d.). In these spaces, designed for learners between the ages of eight and twelve, educators encourage students to form a community in which they answer their own questions about a given topic. These learning spaces allow for a lot of autonomy in that students are responsible for their own investigations; they organize their own groups, generate plans through which they will solve the given problem for the day, and choose their own topics. This sense of freedom allows learners to develop a self-motivated and passionate project of their choosing (School in the Cloud, n.d.).

SOLE spaces are heavily based on technology. Dr. Mitra, who also developed the organization School in the Cloud, strongly believes in the importance of technology and computers in learning experiences. Therefore, in SOLE lessons, each group of roughly four students is given a computer on which they conduct their investigations. Additionally, there are an abundance of online resources available through School in the Cloud that allow teachers to connect with one another, and to allow their students to collaborate from remote locations around the world (School in the Cloud, n.d).

While all of these resources make for an incredibly engaging and self-motivated learning experience, there are many limitations to its implementation. First of all, the presence of several computers with Internet connection is absolutely essential for these kinds of learning activities. While many classrooms across the nation have these resources available, there are still schools where this necessity would create a limitation. Additionally, for students who do not have these kinds of resources available to them outside of school, there is a clear disconnect between school and the outside world when all learning experiences are based on the computer and Internet access. In order for student to most effectively learn and apply the content they are acquiring, there must be some continuity between students' school lives and their home lives.

Additionally, in the current landscape of education, where the stakes are high and students are being tested, many teachers feel that there is less room for these kinds of activities; no longer can classroom teachers devote weeks at a time to investigations and projects. While in theory, these methods will strengthen the necessary skills to perform well on state-mandated assessments, the reality of practicing teachers is very different. In my experiences in local classrooms, teachers feel an incredible amount of pressure from their administrators and the parents of their students to teach test-taking skills and prepare students to pass exams. Therefore, there is a distinct disconnect between the kind of work done by theorists such as Dr. Mitra and the lessons that are being implemented in secondary education. These kinds of gaps need to be closed in order for project-based instruction to be most effective.

In general, the implementation of technology into educational spaces is not always the sort of catch-all solution that many people make it out to be. In order for technology to work effectively in a classroom, teachers need to be taught how to most appropriately use it; simply adding technology to a classroom will not enhance the learning experiences of its students. Most often, teachers will use new technologies for personal purposes such as seating charts and lesson plans, as these kinds of uses are simpler to incorporate. While the proper inclusion of technology could greatly enhance the learning experiences of students, professional development needs to be used to prepare teachers the instructional value of these technologies in addition to their uses so that they can be an effective use of school budgets (Herold, 2015).

Gender biases in STEM spaces. In addition to the many financial constraints that limit who has access to project-based learning opportunities, there are many nuanced ways that exclude women from STEM spaces. In *Unlocking the Clubhouse,* Jane Margolis and Allan Fisher (2002) investigate the ways in which women are pushed out of computer science programs. Margolis and Fisher conducted a study at Carnegie Melllon, the home of one of the most prestigious computer science programs in the country, in an attempt to understand why so few women were enrolled in their program. Their study examined the ways in which society sets women up to feel as though they cannot succeed in programming (Margolis, 2002).

Margolis and Fisher describe computer science as a “boys’ club”; most of the projects the students are asked to complete are geared towards traditionally male interests such as violent video games. While there are many women who share these interests with their male counterparts, the lack of gender-neutral tasks in many computer science programs creates a large gap in the enrollment of male and female students in these courses of study (Margolis, 2002).

Generally, and according to Margolis and Fisher, researchers have found that women tend to be attracted towards projects that incorporate personal interaction in which they can feel involved. Therefore, these researchers made many suggestions to the coordinators of Carnegie Mellon’s program that incorporated these preferences. For one, STEM spaces need to incorporate more comprehensive projects that require a variety of skill sets. These kinds of projects will also allow students to see the impact of their work more easily, which will benefit all learners. Additionally, in order to combat the sometimes hostile environment of a male-dominated space, there need to be support groups and encouragement for the women in these programs; often times, women who start off in STEM spaces are inclined to drop out, as they do not feel supported or included. The creation of inclusive curricula and groups for women in STEM will help to combat this issue (Margolis, 2002).

Sherry Turkle and Seymour Papert (1990) investigated similar phenomena between hard and soft skills and learning styles. Soft skills, which do not include programming, building, or the more technical skills associated with STEM fields, are often viewed as typically female skills, while hard skills and learning styles are equated with maleness. Additionally, in the current state of affairs in STEM education in the United States, creative thinking is not valued nearly as much as computational fluency. Therefore, students who think in this way are often excluded or dissuaded from STEM careers. Unfortunately, studies have shown that most of these kinds of learners are female: “Our culture tends to equate soft with feminine and feminine with unscientific and undisciplined … we explore the ways in which soft is a valid approach for men as well as women, in science as well as in the arts” (Turkle, 1990, p. 166). When soft skills become more accepted in STEM fields, according to Turkle and Papert, women will begin to feel more included. In turn, STEM spaces will become more inclusive and accessible to a wider range of learners.

The big picture of project-based learning. Project-based learning is often thought to be a complex and intricate way of instructing that will only benefit a few students; it is thought of as cumbersome to teachers and difficult to implement. However, while these kinds of project-based teaching techniques certainly exist, there are many ways to create hands-on learning spaces for students that are low budget, easily incorporated, and conducive to the learning of many different kinds of students. Any sort of teaching methodologies that differ from the standard paper-and-pencil mathematics model are to be considered project-based instruction techniques. In order to make these learning experiences more accessible, educators must be cognizant of the environments in which their students are learning in order to make STEM instruction more relatable and contextualized. In doing so, the STEM education experience will be enhanced and accessible to a wider variety of students.

Chapter 5: Teaching and Learning in a Middle School

I spent the fall of 2015 in a local middle school mathematics classroom. During my time at this school, I worked with a veteran teacher every day in the morning. By the end of the semester, I was fully responsible for a section of seventh grade mathematics, which followed the standards set forth by the *New York State P-12 Common Core Learning Standards for Mathematics*. During my time spent with this teacher and her students, I was able not only to observe the current practices used in a typical seventh grade mathematics class, but I was also able to implement some of the more relevant ideas from current education literature in the United States.

The students in this class, due to a lack of up-to-date textbook, created their own references in an interactive student notebook (ISN). These notebooks, in which the students defined terms, created interactive models, and completed practice exercises, were decorated and maintained entirely by the students. Therefore, they each felt a sense of ownership over their learning. According to my cooperating teacher, in years past, the students have lost or defaced their textbooks, and in reality, they were used very infrequently. However, since the implementation of the ISN, the students kept track of their own work and progress, and engaged with the material far more often.

When introducing new concepts, or reviewing old ones, with these students, my cooperating teacher and I did our best to do so in interactive ways. One example stands out in particular upon reflection of my time in this classroom; the students were working with adding positive and negative integers, a skill with which they were all familiar. However, we used a variety of manipulative tools in order to strengthen the students’ understanding of additive inverses and how addition functions. Two of these tools were algebra tiles and number lines.

Algebra tiles are small squares and rectangles of varying sizes that allow the students to manipulate the numbers and variables with which they are working, and number lines were used similarly to help students understand the concept of adding and subtracting positive and negative numbers. Below is my reflection upon completion of these lessons, taken from my student teaching journal on September 25, 2015:

> This week in the Math 7 class, students are learning how to add integers. They are doing so in two ways: with algebra tiles and with a number line. The students in both sections of Math 7 were far more engaged with the number line than they were with the tiles; while they seemed not to need the physical tiles to complete integer addition problems, we found that many of the students actually used the number lines to come to their solutions. For that reason, we decided to tape the number lines to the table so that students could use them in the future until they get more comfortable adding positive and negative integers mentally. Regardless of the preference that the students showed between these two methods, it was important that they learn each one; the tiles helped them to understand zero pairs, while the number line demonstrated the difference between positive and negative numbers.
>
> I was happy to see the hands-on way in which my cooperating teacher teaches integer addition; rather than giving students the short cuts and rules up front, she helps them to develop them independently. The students are very engaged in her class, and I believe it is because of the independent nature of her instruction.
>
> While this hands-on form of instruction is a great overall classroom environment, it of course has its downfalls. Creating the Interactive Student Notebooks is a time consuming process, and occasionally cutting and gluing takes up more class time than what we have planned. This takes away from the math instruction time on those occasions. However, I believe that it is worthwhile to take this time as it gives students ownership over their work.
>
> Other modifications have had to been made to this style of teaching based on the students in our class. Obviously, all students should learn math, as it is intrinsic to understanding the ways in which the world functions. However, mathematics instruction needs to be individualized based on students needs; for example, we have one student in our class who has dysgraphia and needs to take his notes on the computer. Therefore, he cannot make the ISNs with the rest of the students. My cooperating teacher and I have worked closely with this student to ensure that he is still an active participant in class and, most importantly, that he is still grasping the material.
>
> However, modification goes well beyond students with disabilities and formal learning needs; there are two young ladies in one of our classes who seem to lack the confidence to participate in the activities. Though they raise their hands to respond to prompts given by either teacher in the room, they always pose

> their answers as questions rather than statements; they are constantly seeking approval and feedback on their work, desiring verification that they are "doing it right." In the case of these two girls, it has been important that they get one-on-one time with a teacher. Therefore, I often work with them as my cooperating teacher is teaching to ensure that they feel confident that they are on the right track. Neither of these students lack the necessary skills to be successful in Math 7; they just need help to see that they are in fact capable of doing so.
>
> In addition to learning the rules for adding integers, the students have also been working with word problems to apply these new skills. These types of problems demonstrate a lot of the mathematical practices put forth by the Common Core; students need to identify the problem and the important information, and then brainstorm solutions to that problem. They also have to explain their work, often in front of the class. When a part of their explanation is unclear, they are asked to clarify and restate what they have said. All of these practices help them to think more mathematically, and prepare them for the higher-level order of thinking necessary for algebra and other high-level math courses.
>
> Overall, I think that the Math 7 class in which I am working is very well run and effectively prepares students to be successful math thinkers. It will be interesting to see how the students' problem-solving skills develop over the course of the next semester, given the work they have already done.

The significance of the above lesson was the way in which it engaged the students in the class. Of the beginning concepts that we introduced to the students, they struggled the least in understanding this one. Often times, the students would reflect back upon this activity when working with more difficult concepts. For example, when adding and subtracting fractions, we asked the students to recall the direction in which they would move on the number line if the numbers were integers. We taped the number lines to their desks, and during quizzes and tests, the students would often use them as resources.

Direct Instruction

In this particular seventh grade class, my cooperating teacher used direct instruction rather than project-based or discussion-based lessons. These lessons were very teacher-focused and the students had little opportunity to work closely with the material. While I did my best to start mathematical conversations with my students during the lessons that were solely my responsibility, they were often at a loss, as the necessary communication skills had not been properly scaffolded. However, there were many reasons for the decision to use direct instruction over other teaching techniques. At this school, the administration is incredibly test-driven. The teachers are expected to teach in such a way that their students perform well on the state mandated tests. Therefore, my cooperating teacher felt external pressure to deliver the material to her students, rather than allow them to make their own connections. This pressure is not uncommon, expecially at the middle school level, and is one that future educators in the field of STEM must learn to navigate.

At the middle school level, routine is incredibly significant; when students know what to expect in a classroom each day, they are more likely to focus on their work. Therefore, many of the practices that I observed and adopted during my time at this school were focused on creating a sense of predictability in the classroom. Below is a description of the routine that had been developed in the classroom, taken from my journal on October 11, 2015:

> My cooperating teacher manages her classroom very well. She has established a regular routine for her students so that they know exactly what to expect each day when they enter her room. Every day, they check to see what materials they will need at the front of the room. After that, they have each been assigned specific roles: one student per group gets all the papers for the day, another gets the folder, and the third student gets the basket of materials and the trash can. Then, they are expected to trim any papers that will be put into their ISNs and wait for further instructions. It took the students a few days to get used to this routine, but now they come in each day and fulfill their roles quietly and calmly.

As evident from the above excerpt, the students in this class were prepared each day to learn, without having to adjust to whatever the day’s activities were. Direct instruction was a significant part of this routine, and it added to the predictability of the classroom environment.

However, since the students, though focused, tended to be less engaged in lessons in which we lectured or delivered information, we included lessons that got the students out of their seats as well. We very often played games that encouraged the students to use what they learned to compete against one another. The students were incredibly receptive to this sense of competition and tended to engage with the material more deeply in these settings. For example, we frequently incorporated “Table Challenges,” in which the students worked on problems independently, and then collaborated with their group until the agreed upon an answer. Finally, their answers would be judged, and we would keep score, giving the winning table a prize at the end of the period. While competition in the classroom has often been called into question, it was a technique that worked well in this score-driven district. The students’ positive response demonstrated the importance of understanding the classroom environment when planning; while this competitive activity worked in this school with these students, it may not work in all settings. Teachers must understand their students’ learning preferences before they can implement specific plans.

Professional Growth

During my time at this middle school, I learned a lot about the future of mathematics education. Because the mathematics department at this school did not use textbooks, my cooperating teacher was incredibly involved in the development of seventh grade curriculum. She was constantly researching the best way to teach the new concepts in the standards, and even as a veteran teacher, she reassessed her teaching practices each year. Because I was immersed in this environment of investigation and evaluation, I was able to reflect upon the teaching practices I found most effective in a middle school mathematics classroom. My growth as a future educator is outlined in this entry from my journal, taken from November 22, 2015:

During my time in this middle school I learned a lot about myself as a future educator. I absolutely loved going in to school each day, and I am most proud of the relationships I formed with my students. I feel as though I knew them on a very personal level; I was aware of their interests and hobbies in addition to their academic strengths and weaknesses. This was an important skill to develop during my candidacy semester. As I have progressed through my teacher preparation program, the one thing that has remained a constant has been my desire to build strong relationships with my future students. My time at this school helped build my confidence in my ability to do so. Especially when I am not held to certain constraints by another teacher, I think that I will be able to incorporate my students' interests and needs into lessons in a smooth and cohesive way.

These relationships with my students helped me realize the importance of individuality in the classroom. As I was saying goodbye to my students, I recognized that I had a different relationship with each of them, and this variation helped all of the students to learn. However, while these emotional connections were important, I also learned so much about teaching math and pedagogy from my cooperating teacher. Especially since her district does not have a text book or a curriculum other than Common Core, she really showed me how to evaluate material to determine what will best help build student understanding. She also helped me find a balance between procedural material and problem-solving lessons.

Overall, this school is a fairly homogeneous school, and therefore the hidden curriculum tends to perpetuate these similarities among students. In the future, I think I will probably prefer to work with a more diverse population of students; in these types of settings, it will be even more important to understand my students as individuals. However, this school was an excellent starting point for me; I was able to develop my basic teaching skills in a school population consisting mostly of students with good "school skills." I am now prepared to work with students who may not have had the same experience as those at this school.

Outside of all of these "teacher skills" that I learned at this school, my time in this classroom really strengthened my confidence to be a good teacher. I still have so much to learn; however, I have been able to take great strides to become the teacher that I one day hope to be this semester. Even though I was guided and influenced by my cooperating teacher and the other teachers in my school, I really feel as though I was able to develop a personal teacher identity. I may have been using most of my cooperating teacher’s material to keep the students on track, but I personalized it in the way that it was taught. Interestingly, she would teach the class first period, and I would do the same lesson fifth. Her lesson's were always organized and efficient, but she tended not to interact with the students about anything unrelated to the lesson. On the other hand, while I was of course focused on content, I tried to find some time each day to allow the students to let me get to know them. I also tried to share details about my own life, such as my former job as a waitress, with my students so that I could become more human for them; Mrs. Gangemi almost never did this, though no explanation was given for why. This difference, though small, helped me to feel like an independent teacher. I am excited to continue to develop this identity over the course of the next semester.

My experience at this school also shed light on the work of Darling-Hammond and Ravitch, in that the effects of standards-based instruction were incredibly apparent. In their work, both of these scholars demonstrate the ways that standardization and high-stakes testing have had negative effects on the experiences of students. Since the implementation of the Common Core State Standards, the teachers at this school have been working tirelessly to match their curriculum to the new standards. Additionally, much of their work is focused on the goal of students passing the state exams at the end of the academic year. As outlined in Ravtich's (2010) book, this focus on high stakes testing can be detrimental to the learning of students, especially at the middle school level. My cooperating teacher showed me an archive of projects and exploratory activities that align directly with the work of Boaler and Humphreys (2005) while I was working in her classroom. However, she expressed her concern in using these projects under the new standards. Especially now that students' test scores are so heavily weighted in their teachers' evaluations, many school districts are choosing a more direct, straight-forward approach to teaching the material. Unfortunately, this method does not allow students to apply their skills to real-world contexts, a form of acquisition proven to be more effective by Boaler and Humphreys.

This high-stakes culture that is currently present in schools across the nation was made even stronger in New York due to the passage of a bill by Governor Cuomo increasing the weight of students' test scores on teachers' annual evaluations. Each year, teachers are required to complete an Annual Professional Performance Review (APPR) with their administrators. The APPR, based on students' test scores and administrator observations, provides teachers with a rating, namely ineffective, developing, effective, and highly effective. While Governor Cuomo is currently re-evaluating this method of assessing teachers' competencies and considering reducing the weight of students' test scores in teachers' ratings, my experience in this school was incredibly focused on the implementation of this new APPR. These ratings, especially in the cases of new, un-tenured teachers, are considered when evaluating teachers at both the school- and state-wide levels. For the first time, fifty percent of a teacher's APPR rating is based on his or her students' test scores (Fact Sheet, n.d.). With such weight associated with students' performance on standardized state tests, it is no wonder that there is a push to move away for inquiry-based learning and into direct instruction classrooms.

The focus on standards and high-stakes test that makes up the current climate of education in the United States has narrowed many teachers' instruction. Many of these teachers have shifted from a project-based and hands-on form of instruction to a model of direct instruction. My experience within this culture has led me to reflect upon how I will implement the material I have learned during my four years of undergraduate study. My cooperating teacher at this middle school demonstrated the difficulties of incorporating engaging material when there is so much pressure from the administration to focus on test scores. However, I am committed to teaching mathematics in an engaging way, and anticipate that my future students will see the same results as their peers, if not better, due to their deeper understanding of the material.

Chapter 6: Professional Development in a High School

During the spring of my senior year, I was placed at small public high school, where I completed my full time student teaching experience. During this semester, I took on full responsibility of three of the five classes taught by my cooperating teacher. These courses were Algebra II with Trigonometry and Onondoga Community College (OCC) Pre-Calculus. The students in these classes were mostly juniors and seniors in high school; in contrast to my placement the previous semester, I got to experience students nearing the end of their high school career, and especially in the case of the OCC pre-calculus course, higher-performing students. In combination with the other experiences I have had during my time in a teacher preparation program, this semester was incredibly formative in developing my picture of the current landscape of STEM education in the United States.

This high school is a very different district than the one at which I was placed in the fall of my senior year; its student population is significantly more diverse, and, as it is located on the outskirts of the city, many of the students come from lower-income families. There is a high population of students enrolled in the English as a New Language (ENL) program, and the state test scores are much lower at this school than they are at their more suburban counterparts.

Teaching in this kind of environment proved to be an incredible learning experience. During my time at this school, I focused on incorporating writing into my teaching practices, asking deeper and more meaningful questions, and providing students with exploratory opportunities to engage with the material. Additionally, my Algebra II class followed a flipped classroom model, in which the students watched videos of content lectures at home in lieu of homework, and engaged with the material through practice problems and activities during class time. This kind of model was a new experience for me as a novice teacher, as I had more freedom with what I could do during class time. Therefore, I was able to experiment with a variety of teaching techniques and practices during this semester with my first period class, most of which will be outlined in this section of this work.

The Incorporation of Writing in STEM Classes

A major focus of my teacher preparation program was the development of academic language in a secondary classroom. Essentially, it is incredibly important that students not only learn the procedures associated with mathematics, but also the appropriate way to communicate their ideas in a technical and mathematical way. Academic language includes technical vocabulary, but it also focuses heavily on the ways in which students talk about, write about, and demonstrate their understanding of the content. For my final semester in this teacher preparation program, I chose to focus on helping my students develop their ability to write about mathematics, a skill that is often forgotten in STEM classrooms.

Research has shown that it is important that students learn how to write about the procedures with which they are becoming familiar: "Students become better writers and thinkers of mathematics when they have regular opportunities to write about mathematics" (Beck, 1999, p. 62). In order to incorporate this practice into my classroom culture, I began to ask the students to write a few weeks into my semester with them. I would try to assign a written response at least once a week. In one such assignment, I asked the students to produce a graph of a polynomial function, to identify different aspects of that graph, and then to explain, in words, the process by which one graphs equations to someone who had never graphed before.

This activity was one of the first times I asked the students to write technically about mathematics, which is reflected in their responses. The responses of Students 1-3 (Appendices I-III) are indicative of the work of the rest of the class that day. Student 2 (Appendix II), for example, showed a strong understanding of almost every aspect of graphing polynomial equations; this response is incredibly detailed and understandable to an outside reader. However, this student lacked a fundamental understanding of the sign of a graph, which greatly affected the given response. Students 1 and 3 (Appendices I, III), on the other hand, generated the correct graph, but their explanations lacked more technical language. Both students could have used a more nuanced and discipline-specific vocabulary in their response. In my written feedback, I asked these students to consider their language as they continued to develop their mathematical communication skills.

Instead of trying to assign a grade to their writings, a practice discouraged in *Mathematics Assessment: A Practical Handbook* (Beck, Bush & Compton, 1999), I chose to respond to them. This promise I made to my students to construct written responses whenever they were asked to write helped them understand the importance of this practice; it also created an environment of mutual respect in which I was able to be open and honest with my students.

In addition to mathematical writing, it is incredibly important to help students develop an ability to think critically about their own learning experiences (Beck et al., 1999). Each Friday, I would ask my students to reflect upon the week, thinking about their own learning, my teaching techniques, and what was working to help them develop their conceptual understanding. These reflections would be collected so that I could track the students' progress. They proved to be very formative in my thinking related to the teaching decisions I made, as I was able to incorporate the constructive criticism and preferences of my students into my lesson plans. These personalized learning experiences helped my students feel more connected not only to me, but to the material as well. Additionally, the acceptance of students' ideas in my classroom allowed them to feel respected and heard, which made them more willing to take my class seriously.

Overall, this practice enhanced my students' learning experiences and my own teaching practices.

Reflections also served as a form of self-assessment, which is an important skill for high school-aged students to develop (Beck et al., 1999). The students were asked to think critically about their own learning, which is a unique opportunity in this high school. Not only did they need to think about what kind of content they were coming to understand versus what they were finding difficult, but they also had to think about methods of teaching that best suited their learning. I constantly asked them to consider the kinds of activities in which they learned the most, and in the cases of activities that did not work, I asked them to tell me why. Metacognition is a critical skill, especially in the case of learners of mathematics; being able to identify the ways in which they are thinking and approaching a problem will ultimately help students develop problem-solving techniques in the future.

In one reflection, I asked the students to reflect upon the strategies they used during group work that week. One student made the following statement: "It works when you work on separate problems and then check each other's. It doesn't work when on person does all the work". While this quote may seem to reflect basic practices of good group work, it was a monumental observation for this student, who up until this point, avoided taking responsibility for the assigned for at all costs. In asking this student to think about the work done in class, it allowed for self-reflection that led to a shift in responsibility from myself to this student on an individual level.

Beck et al. (1999) also discussed the importance of providing students with strong examples of writing in order to help them develop their mathematical writing skills. Therefore, I would always write a reflection at the end of each week as well. I would share this reflection with the students Monday mornings, not only so they could see an example of what I was expecting when I asked them to reflect, but also so that we could develop an honest relationship within our written interactions. Very often, the students would disclose information in their reflections or their responses that they were not comfortable sharing in person. For example, in the attached student sample, the student shared feelings of discouragement over a team name (Appendix IV). In class that week, the students had participated in a team challenge in which they needed to name their teams. One team selected “Failures” as their name. Upon reflection, I should not have allowed them to use this name; therefore, I was aware of this misstep in my own teaching practice. When the aforementioned student brought up this incident, I found an opportunity to apologize for something that I had let get out of control. This sample is just one of the ways in which incorporating writing into my classroom allowed me to connect with my students on a more personal level.

Overall, writing in a mathematics class proved to be an effective teaching strategy that I had not seriously considered before this semester. The students developed strong reflective skills, built their mathematical vocabulary, and learned how to write about and communicate technical topics. It also provided me with an opportunity to connect with the students on a personal and more private level, which opened a line of communication I was unaware could exist in a mathematics classroom. After having the opportunity to experiment with this strategy in my classroom this semester, I am sure that writing will be a critical part of my future mathematics classes.

The importance of a good question. Questioning is a skill that many pre-service teachers lack; especially within the content of mathematics, it is very easy to fall into the habit of asking questions that promote lower-order thinking. At the beginning of my two-semester student teaching experience, I was certainly guilty of asking simple questions that often resulted in yes or no responses. These questions included "What is the next step?" and "What do I do when I see a division sign?" While these kinds of questions helped the students develop their procedural fluency, they did nothing to promote conceptual understanding and problem-solving skills. As I continued to become more comfortable in front of a classroom, I began to realize the importance of asking questions that required more of my students.

The work of Dacey and Gartland (2009) in "Getting to Know Our Students" focused heavily on the significance of learning about students in order to differentiate instruction for their learning needs. One of the techniques they suggested to accomplish such a goal is to ask probing questions during in-class assignments. Examples of these kinds of questions are "How do you know?" and "Can you restate what she just said?" (Dacey & Gartland, 2009, p. 73). While these questions require students to think about their own learning and problem-solving process, they also allow teachers to understand what their students know, and how they think about and communicate mathematical ideas (Dacey & Gartland, 2009). This kind of knowledge is indescribably useful when planning future lessons, developing methods of assessment, and gauging students' understanding.

Stein and Smith (2011) also address the issue of questioning in a mathematics classroom in their article *5 Practices for Orchestrating Productive Mathematics Discussions*. This article is designed to help teachers structure class discussions so that students can get the most out of them, which requires teachers to have a strong understanding of their students' learning and thought processes. Questioning is an effective strategy in developing this understanding (Stein & Smith, 2011).

According to Stein and Smith (2011), there are two types of questions that help format a discussion in a mathematics classroom: advancing questions and assessing questions. Advancing questions encourage students to move beyond their current level of thinking. Some examples include, “How is your answer the same or different from…” and “Can you solve this in a different way?” On the other hand, assessing questions allow the teacher to clarify the students’ work and thinking. Questions such as “Can you explain to me how you solved this? And “How do you know that is the correct answer?” require students to think about their own thought processes in a critical way. Additionally, they allow teachers to better understand they ways in which students are approaching problems. (Stein & Smith, 2011).

As I began to understand the importance of asking deeper questions, I started planning more engaging lessons. In one such class period, I adapted an activity from betterlesson.com in which the students worked in groups on a problem that incorporated the trigonometric functions with which the students were working (Appendix V). During this activity, I resolved to provide as little guidance as possible, allowing the students to work through the problems with their classmates. I focused heavily on my questioning during this lesson. While the students were working through the activity, I asked questions such as “Does this make sense?” and “How can we use what she just said to help us solve this problem?” The students were frustrated at first; they were not accustomed to teachers not answering their questions. Many of the students wanted me to tell them whether they were right or wrong. However, as they became aware that I was not going to give them the answers, they began to work more closely with the other people in their groups. Simply through the deeper questions I asked that day, the students developed a better understanding of the material. They also began to understand how to properly communicate their ideas to their classmates, a skill that up until this point, I had felt they were lacking.

Questioning is a pedagogical area that is overlooked in many STEM classrooms; it is very easy for teachers and students alike to become dependent on activities that focus on content-based, low level questions that help students identify procedural patterns. As I continue to develop as a future educator, I will focus on the types of questions I am asking my students, taking care to ensure that they are deep questions that promote metacognition and conceptual understanding.

Student-based, exploratory activities in STEM classrooms. Often times, when people are asked to picture a STEM classroom, they call to mind a rather boring image: a teacher in front of the room, equations on the board, and limitless pages of notes. However, the current landscape of STEM education in the United States paints a very different picture. According to experts in the field such as Boaler, Kilpatrick, and Wiggins, it is the responsibility of teachers to create engaging and interactive spaces in which students can learn STEM. During this semester, more so than in my middle school placement, I had the opportunity to experiment with these kind of activities in my classroom.

In my student teaching semester, I was greatly influenced by the work of Boaler and Humphreys (2005). These education scholars advocated for discussion-based instruction where the students were expected to make connections themselves (Boaler & Humphreys, 2005). The attached activity, referred to as the Drawbridge Problem, was adapted from betterlesson.com for my Pre-Calculus class, and closely modeled the work of Boaler and Humphreys (Appendix V). While this activity easily could have been completed independently, I chose to have the students work on it in groups of three. The students had only just been introduced to the concept of inverse trigonometric functions. Therefore, this task challenged their understanding and required them to make new connections. Despite its short length, this activity took two days, one for work and one for discussion. All of the work done and the conversations we had the subsequent day were student-led. My placement in the room was very intentional (Appendix VI). While the students were at the front of the room, working on the board, I as sitting at a student table. This placement allowed them to take the lead, and it let me to take the role of facilitator and questioner. This choice was very important for this kind of lesson, as it fostered a sense of self-motivation and independence.

Initially, the students were very frustrated with this activity, as I refused to tell them whether they were correct or incorrect. This technique was one taken directly from the work of Boaler and Humphreys (2005), who focused on the students' processes and explanations rather than the correctness of their responses. However, once the students discovered that they were not going to get much information out of me, they turned to their classmates. At this point, they began to have incredibly deep conversations about the mathematics with which they were working.

The final part of this activity, which asks the students to construct a graph of the equation they generated, proved to be the most difficult for the students; the graphs of inverse trigonometric functions had not yet been covered. Many of them plugged the equation into the calculator to get an image of the graph, and assumed that they were done. They were quite distressed when I asked them to explain how they generated their graph, without the use of their calculator. Again, I refused to give them hints or to tell them whether they were right or wrong. The work the students were completing on this part of the activity led them into the next class period, during which we moved from small group conversations to a whole class discussion.

As the students bounced ideas off of one another, I simply made comments such as "That is a good idea. Let's think about that." or "Let's think about what he just said." These comments align directly with the work of Dr. Sugata Mitra in his concept of the Nanny in the Cloud. In this study, students work entirely independently, simply receiving statements of praise from an adult figure. According to Dr. Mitra, students were able to make the necessary connections with little to no help from the teacher in these scenarios (School in a Cloud, n.d.). While I was skeptical of this work initially, I learned that my students were incredibly capable of drawing conclusions with minimal help from myself. In just ten minutes, the students had a graph drawn with a compete explanation. There was a sense of accomplishment amongst the students; they moved from feeling frustrated and confused to feeling like experts of the content. They were also more open to these kinds of activities in the future, which enhanced their learning experiences in general.

A final application of theory in practice. Working in a high school for the final semester of my college semester was formative in my growth as a future educator; being given the freedom to plan and execute lesson in three classes gave me the opportunity to experiment with pedagogical techniques that I hope to incorporate into my own classroom in the future. This experience also allowed me to apply much of the theory I studied during my four years as an undergraduate into a realistic setting. While there are still many aspects of the current landscape of STEM education that make it difficult to incorporate inquiry-based lessons into the daily routine of students, I learned during my time at this high school that it is not an entirely unrealistic goal. Upon completion of this semester, I know that student-centered, discussion-based lessons will be a part of my classroom culture with my future students.

Chapter 7: Final Thoughts

The collective work of this auto-ethnography provides a clear picture of the current landscape of STEM education, and it also makes suggestions at changes to be made in the future. Currently, STEM educators in the United States find themselves at a crossroads with respect to their pedagogical choices; while they are feeling immense pressure from their administrators to teach to the state tests in order to warrant the best student results, almost all of the current academic literature in education suggests an entirely different teaching approach. Scholars in education promote a culture of self-directedness and exploration in STEM classrooms. Students who are driven to work towards solutions independently or with the help of their peers develop stronger problem-solving techniques, a skill set directly transferrable to many fields, both within and outside of STEM. It is the job of the teacher to make the instructional decisions that will best benefit their students, incorporating as many inquiry-based opportunities as possible.

I claim that this inquiry-based style of instruction could best benefit the students of the United States and help them develop a deeper understanding of the content. Teachers should make use of hands-on and project-based instruction techniques, including real-world, contextualized problems and investigations. Additionally, discussions and reflection should be regular parts of all classrooms, but especially those in the field of STEM. The ability to engage in metacognition and think about the ways in which students learn best are important skills to facilitate and encourage in a STEM classroom.

As a new teacher, I am armed with the most up-to-date literature and methodologies. However, finding a way to fit those strategies into the rigid curriculums used in public schools today has proven to be a difficult task. After all of my teaching and learning experiences during the course of this study, I plan to be able to incorporate as many discussion-based activities, with many points of access, as I can. After completing this study, I am committed to utilizing project-based instruction, making my material accessible to all kinds of learners, and allowing my students to work closely with the material in class in order to draw their own conclusions.

However, at the completion of this study, I am aware that there is much work to be done in the field of STEM education reform. Many of the topics covered in this project are avenues for complete studies and investigations. Specifically, scholars in education should consider the ways in which certain demographics of students are left out of STEM spaces and study the ways to open these doors and close the existing gaps. Additionally, there is still much research to be done on the effects of project-based learning; while this kind of learning, in combination with inquiry-based instruction, has proven to be a positive experience for the students in my personal experiences, researchers should consider the tangible effects of this pedagogical decision.

The implications of this work, and the research yet to be done in this field, are huge in the complex world of STEM education. The rhetoric surrounding this field suggests that major changes need to be made in order for students to catch up to their international peers; science, technology, engineering, and mathematics are up and coming fields, and educators in these fields should prepare their students to be active members of these communities.

Through the comparative lens of this study, it is clear that the education system of the United States has much to learn from its international peers. Namely, the sheer energy and dedication of the reform movement in Chile should be considered by students, teachers, and scholars alike in the United States. The demands made for change by Chilean reformists are impressive and permeate the culture of the country, a goal still to be accomplished by reformists in the United States. Additionally, my work in Santiago, Chile solidified the claim made in this study that discussion-based instruction benefits the learning experiences of students. Through international scholarship and exploration, STEM education in the United States could be greatly enhanced in the years to come.

Overall, my study aims to make claims about the current state of affairs in STEM classrooms across the United States. While education in general is currently undergoing a huge overhaul, with politicians and reformists looking for ways to improve the schools in this country, it is an exciting time to be a STEM educator. With a new focus on the reasoning and problem-solving skills associated with the learning of mathematics and science, teachers are given the opportunity to create rich learning environments for their students. While the balance of high stakes testing and enriching instruction is a difficult one to master, it is clear from the content of this work that it is not an impossible feat.

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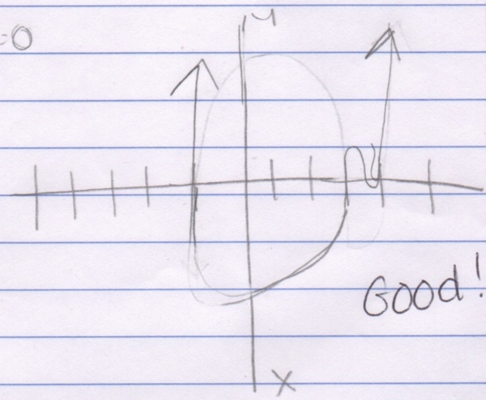
Appendices
Appendix I

(1)

[redacted] Student 1 2/23/16

① $(x-4)^2(x+1)(x-3)=0$



Good!

$(x-4)=0$ $x+1=0$ $x-3=0$
$x=4$ $x=-1$ $x=3$

② $-\infty, \infty$ As $x \to -\infty$, $f(x) \to \infty$
As $x \to \infty$, $f(x) \to \infty$

③ you would set each factor to zero that way you will get where the points cross the x-axis if something is squared it will then bounce on the axis.

Your understanding of the vocabulary is very clear in this response! I'm really pleased with your explanation, you obviously understand this material. Keep up the good work in class, it's clearly paying off! :)

Appendix II

②

Student 2

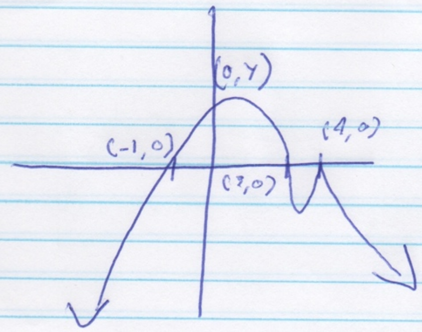
[redacted]

$x=4$ *

Graph $\quad x=3$

$x=-1$

$(x-4)^2(x+1)(x-3)=0$



For a positive 4^{th} degree function, the graph should come from the positive direction. (You just have it flipped)

AS $x \to -\infty$, $f(x) \to \infty$

• $(-\infty, -\infty)$ AS $x \to \infty$, $f(x) \to \infty$

• Solve for the x's. If there is a $(\#-x)^2$ It bounces on the Graph. ← called a factor

Because there is no sign on the equation above we assume it is positive and the Graph should start on the Lower Left part of our Graph. The equation above does not give a y intercept, but if it did It would determine how tall/short the Graph is. But for this exsample a ~~rough~~ sketch should be o.k.

This is a spot on description, except you have the definition of a positive function reversed (remember the function comes from the positive direction). Thank you for taking your time with this assignment!

Appendix III

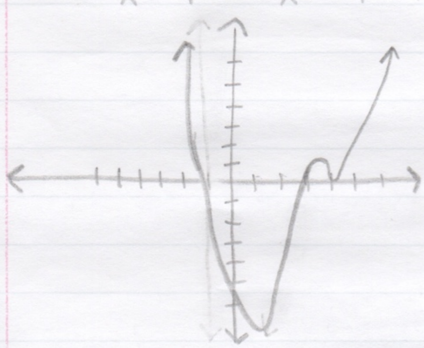
③

[redacted] **Student 3** 2/23/16

- $(x-4)^2(x+1)(x-3)=0$

$x-4=0 \quad x-4=0 \quad x+1=0 \quad x-3=0$

$x=4 \quad x=-1 \quad x=3$



Excellent!

- End behavior = As $x \to +\infty$ ∞ As $x \to -\infty$ $-\infty$

Awesome use of mathematical notation!

- you would set ~~everyone~~ each factor equal to zero than they would graph them as the zero's and if it was squared you would bounce it on the x axis.

Good description! I definitely think a new student could use this. Thank you for putting in the effort in this activity. All of your hard work is definitely showing!

Appendix IV

The past few days went great except when I was on the team of "failures." Everything worked, nothing didn't. I would make it a flipped classroom again~

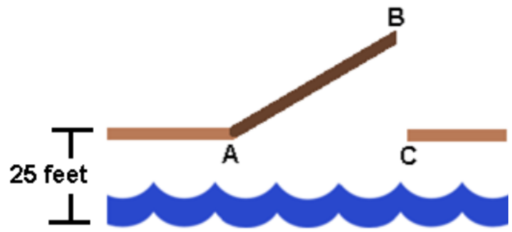
[redacted] I want to apologize for your team name. I really should have addressed that and handled the situation better. I hope that you know that I don't think of you, or any of your classmates, in that way. You have been working really hard, and I appreciate all of your effort. In absolutely no way are you a failure, and I'm so glad you were honest about your feelings with me in this reflection.

Appendix V

Name____________________ Period_____

The Drawbridge Problem

A drawbridge is to be constructed over a waterway in Kaliningrad, Russia. $\overline{AB}$ is the portion of the bridge that pivots and A is the pivot point. The length of $\overline{AB}$ is 43 feet. Let θ represent the angle that is formed by $\overline{AB}$ and $\overline{AC}$ as the bridge opens up. The distance from the surface of the water to the bridge is 25 feet.



a) Suppose the bridge is open to a 62° angle, what would be the distance from $\overline{AC}$ to the top of the bridge?

b) Suppose the bridge is open to a 62° angle, what would be the height of the bridge above the water?

c) Suppose the bridge is open to a 14° angle, what would be the height of the bridge above the water?

d) Suppose that you are operating the drawbridge and must decide what angle to open it based on the ship that is coming through. You do not want to open it all the way, because it is a waste of power, so you only open it to the angle you absolutely need. If the top of the bridge must be 42 feet above the water, to what angle will you have to open the drawbridge? Show work or explain how you got your answer.

e) What if the top of the bridge must be 33 feet above the water? To what angle will you have to open the drawbridge?

f) What if the top of the bridge must be $(x + 25)$ feet above the water? To what angle y will have to open the drawbridge?

g) In the equation you wrote in part f, what does the input x represent? What does the output y represent?

h) Try to sketch a graph of this function.

Appendix VI