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How Can Teachers Increase Student-student Discourse In Math Classrooms?

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HOW CAN TEACHERS INCREASE STUDENT-STUDENT DISCOURSE IN MATH CLASSROOMS?

by

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DEDICATION

To my loving wife Sheng and beautiful daughter Freya. Your love and support motivates me everyday to be the best version of myself. To my parents for always supporting my higher education ventures. To Deb, my content reviewer and mentor, your knowledge and perspectives in math classrooms have taught me a lot about being a great teacher. To my Capstone Committee. Your patience and guidance has allowed me to triumph over many challenges in order to complete this project.

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ABSTRACT

Vang, A. Creating Unit For Secondary Mathematics With An Emphasis On Learning Through Student-Student Discourse. (2021)

This capstone aims to answer the question, *How can teachers increase student-student discourse in math classrooms?* It is answered through the creation process of a curriculum heavily based on students learning through discourse with their peers. This curriculum developed by the author aims to create unique learning experiences for students. Opportunities to struggle and learn through conversations in a safe environment is the basis of the curriculum. There is also a strong emphasis on high levels facilitating learning through student-student discourse which is typically uncommon in a traditional mathematics classroom and curriculum. Lastly there is a reflection on the creation process of the curriculum. The author concludes that the first version of the newly developed curriculum will not be the last because improvements are crucial to improve the effectiveness of the curriculum.

CHAPTER ONE

Introduction

Background

Math is a subject that I was never good at and it is ironic that I became a math teacher. Growing up, I found myself distracted in math classes, often daydreaming and thinking about how math could be applied instead of following examples of how it was done. It was not until graduate school that I realized why I struggled so much in math classes. I always thought I was just a slow thinker compared to my classmates and would often find myself multiple problems behind them. I struggled with doing the math quickly because I was more interested in talking about the implication of what we learned. The more I struggled, the more I wondered why I liked math if I was not that great at it. This led me to explore my capstone question: *How can teachers increase student-student discourse in math classrooms?*.

This realization came during a math class I was taking during graduate school. A Geometry professor brought up the topic of mathematical maturity. I was surprised that a part of math so basic and fundamental was only introduced in a math class 18 years after my first day of math class. We came upon this topic of mathematical maturity because the professor knowingly gave us group work that was too difficult for us to complete individually. She explained to us that the purpose of this and future group work exercises was to create opportunities in which we could grow our mathematical maturity through conversations and experiences. My mind was blown. Years of struggling in math classes and I never once had been given the opportunity to express my thoughts on mathematics with my peers. The questions asked in these exercises were different from the mundane *follow the procedure* group work I was presented with in my previous math classes. We were forced to have conversations on the questions and were held accountable to ensure each group mate understood what was being discussed. After this experience, I began to search for ways I could incorporate conversations into the math classroom in order to help cultivate students' mathematical maturity.

Mathematical Maturity

Mathematical maturity is an integral part of student development in the math classroom. It is what allows them to look at problems from different perspectives and have crucial conversations about the "why" in mathematics (Fennema & Romberg, 1999, pp. 13-14). When students have high math maturity, they are more likely to be reflective learners and under that, mistakes are learning opportunities. They are also less likely to freeze up and can persist when faced with challenging questions.

Unfortunately, in most American math classrooms there are limited opportunities for students to develop their math maturity. Instead, our classrooms are filled with assignments and teaching methods that only show students the "how" part of math (Fennema & Romberg, 1999, pp. 12-13). This leads to many students believing that they "aren't math people" because they cannot keep up with the redundant follow-the-instructions lessons commonly used (Fennema & Romberg, 1999, p. 13). These activities have very few, if any, opportunities for students to have conversations about mathematics and their learning. To develop mathematical maturity in students, we must create student-centered classrooms that offer opportunities for discussion and reflective learning (Fennema & Romberg, 1999, pp. 27-30). Only then can we begin to change the current narrative of the math classroom (Fennema & Romberg, 1999, p. 13).

Experiences in Schools

For the past two years I have worked in numerous school settings at various grade levels as a substitute teacher. Even though every situation was unique, one thing was constant, the math classroom. During two years I was a substitute teacher, there was not a single math classroom where conversations were included in lessons. Classroom after classroom, I saw how math was still an instruction manual. Textbook problems were heavily used, and quantity was more important than quality. Students were unenthusiastic and math class became a chore. Even though I had not been a middle or high school student for many years, these classrooms were still the same.

I remember teaching in a math classroom and looking at the work assigned for the week by the teacher. Students had been given 60 problems to be finished over the course of five days. These problems were just different versions of the same problem; and in the next week, students knew that these problems would not matter anymore. What mattered was that they got it done before the deadline.

Walking around the room, I observed the culture of the classroom. The same cliques that existed during my time in middle and high school were still in existence. This disturbed me greatly, and it is a big reason I am seeking to improve the experience of students in math classrooms. I believe adding conversations can improve the math classroom because it provides students with opportunities to develop their critical thinking and mathematical maturity.

During my time as a substitute teacher, I often found myself helping students who were too intimidated to approach their usual teacher for help. The product-based learning set up by these teachers created an environment that was not conducive to learning for some students. This resulted in disparities in students' learning, and these disparities increased as the school year went on. Students who did not understand a concept before the lesson ended were left behind to figure things out on their own. I was one of those students, and from my own experience, I know it was not a fun time. I felt that everyone else was moving on when I was just barely starting to grasp concepts introduced weeks ago. It was this feeling that I experienced during my K-12 education which drives me to be a better teacher every day.

Need for Discourse

Math classrooms in most schools still look like how they did decades ago. Math curriculum has not changed much and many teachers still rely on teaching out of the book. This is because there is a lack of new curriculums that focus on students learning through discourse and conversations. Providing teachers with new curriculums that focus on student learning through discourse can help modernize the traditional math classroom. Discourse is key to learning mathematics because it teaches students how math is practically applied and how the skills learned can be applied beyond the classroom.

Academic Safety

Before conversations can happen in the classroom, academic safety must first be addressed (Krall, 2018). Creating a classroom in which students feel safe to express their thoughts and opinions is the first part in creating opportunities for conversations. It is crucial for teachers to realize that many students are coming from math backgrounds in which there are severe gaps in their knowledge, and we must do our best to not have that be the focus of the conversations (Krall, 2018). Students already know that these gaps in their knowledge exist, so it is the teacher’s responsibility to show them that it is okay to have these gaps. By creating an academically safe environment, students will feel more comfortable taking risks. Actions like guessing or explaining how they may have started a problem need to become low risk (Krall, 2018). These are often the starting points of conversations in math and provide opportunities of growth. If teachers cannot provide this space in which students are comfortable taking risks, they cannot expect their students to become independent learners (Krall, 2018).

Summary

I have been a substitute teacher for two years in various schools and settings. During that time, I noticed that math classrooms have not changed since my days as a student despite research identifying more effective instructional practices. Math curriculum and pedagogy have remained unchanged for the most part, and students are beginning to desire more out of the math class. Yearly routines of following instructions and pumping out problems has led to a low number of students taking interest in mathematics.

The math classroom is in dire need of reform and one way teachers can do that is through the integration and increase of conversations and discussions. Math is known to be a class in which students do not talk much.This narrative needs to change in order for math classrooms to be an academically safe environment where students can develop their critical thinking and become independent learners. Teachers must also be aware of the conversation happening in the class and ensure that quality opportunities for conversations are presented to students.

For this first chapter, I discussed my personal experiences in math classrooms and highlighted the need for more increased conversations in math classrooms. In Chapter

Two, I examine different methods in which teachers can begin integrating discussions and conversations into their math classrooms. It includes a deep dive into works by Jo Boaler and her work on inspirational math(s). There is also an analysis of other math talk activities and project-based learning activities in the math classroom. For Chapter Three, I provide a creation timeline, setting, participants, and theories for the curriculum created to help answer the capstone question. In Chapter Four, I reflect on the creation process of the curriculum and what I have learned.

The goal is to find out how math teachers can easily change aspects of their pedagogy and curriculum in order to create more student centered classrooms that include conversations and discussions that support students in becoming life long independent learners. This process will also help answer my capstone question, *How can teachers increase student-student discourse in math classrooms?* Change is slow but it is needed. Finding effective methods now can allow us to do things that seem impossible for math classrooms in the future.

CHAPTER TWO

Literature Review

Context

This chapter reviews different works of literature to help answer the capstone question: *how can teachers increase student-student discourse in math-classrooms?* The first section of this chapter analyzes classroom styles. The second section covers diverse learners. The third section focuses on the types of conversations and their effects. The fourth section investigates mathematical maturity and ways to help students develop it. Being knowledgeable of these topics can help teachers create a curriculum that is responsive to all learners. It might also help teachers create a learning environment that is academically safe in order to have student-led math discussions.

Classroom Styles

Before analyzing how teachers can add conversations to their classroom, it is important to understand different ways teachers can choose to set up classrooms. This is because, according to Brophy (2004), “It is commonly observed that certain preconditions must be in place before motivational strategies can be effective” (p. 26). Brophy (2004) said this as a direct reference to Maslow’s hierarchy of needs which says that lower levels of needs must be met before higher level needs can become operational. The five levels of needs are physiological needs, safety needs, need for recognition, need for esteem, and need for self-actualization (Cadiat & Probert, 2015). This means that students cannot effectively learn and become independent thinkers if physiological needs and safety needs are not met in the classroom. Teachers must be aware of how their rooms are set up so student needs are met in order for learning to happen fluidly.

Espey (2008) stated that seating choice is correlated with student participation and learning but it is important to focus on the individual students and not get lost in grouping certain students. Teachers must also be aware of features in their room like walls and doors as they have been found to have an effect on student interactions (Espey, 2008). The layout of the room is crucial to students' learning because it has a direct impact on what is done in the class, the learning process of students, and how student interaction is perceived (Bolden et al., 2019).

Along with the physical classroom, teachers must also consider their classroom management styles. Teachers often adopt classroom management styles that reflect their responsibilities in the classroom (Berger, 2021). Berger (2021) also stated how teachers' sense of responsibility is not unidimensional but multidimensional as their feelings may change based on different outcomes. The outcomes are responsibility for student motivations, student achievement, relationships with students, and teaching quality (Berger, 2021). Just like the physical classroom, teachers will grow and develop their classroom management styles to best fit their students and themselves. How students perceive a classroom is also largely dependent on how a teacher manages the classroom. The outcomes stated above are easily seen through the lens of a student and teachers must be mindful of how their actions affect their students' learning.

Another intangible aspect of the classroom that teachers have control over is the expectations they set for students. Being clear, consistent, and predictable can help support students who are struggling. Students who experience these types of teaching strategies often become more effortful and engaged in the classroom (Brophy, 2004). Students move between many rooms throughout the day which means they experience a variety of expectations set by different teachers. Removing the stress and anxiety students can have over this by remaining clear and consistent can lead to better learning outcomes.

Teachers must also be aware of how their space can affect how well activities go. Bolden et al. (2008) stated that the most important thing to optimize student learning is to create physical spaces that allow students to engage with each other in activities like discussions and group work. It is also important to note that simply setting up the spaces for these activities does not ensure students will learn effectively; there are many factors at play and the physical classroom is just one of the many parts in the wheel of education. Teachers should explore pros and cons of different classroom setups to see what works for them and their students. Bolden et al. (2008) concluded that learning is different in different environments. What a teacher can accomplish with one classroom setup may not be so successful in another lesson that requires a different set up.

A common layout in the classroom is the rows-and-columns arrangement (Yang et al., 2021). This layout maximizes the space of the room and allows for easy supervision of students. It is also very effective for lectures and the transfer of knowledge but at the cost of having effective peer interaction (Yang et al., 2021). Proximity can also become an issue with this layout. Wannarka and Ruhl emphasized that because proximity and orientation have an effect on communication, it is possible that how desks are configured can also impact interactions.

On the other end of the spectrum there is the semicircular arrangement, which allows the teacher to maneuver from student to student efficiently and effectively. Students who sit closer to each other can see each other's faces, which promotes more student-to-student interactions (Yang et al., 2021). This setup does not utilize the space of the room as effectively but maximizes effective whole group instruction and student interactions. There are many ways teachers can set up the desks in their rooms like rows, clusters, semicircles, and many others (Wannarka & Ruhl, 2008), but there are also many factors at play with setting up the desks. Teachers must be creative to maximize the space of their room while taking into the account the effect it will have on their learning. It is also important to note that sometimes teachers lose the ability to change this aspect of the room because of small classroom sizes or student numbers that are higher than what can fit their space.

Another reason teachers must be mindful of how their classroom is set up is because it has the potential to encourage desirable and undesirable behaviors in students (Wannarka & Ruhl, 2008). Student behaviors have a strong impact on the pace and course of a lesson. If a teacher experiences lessons that are being derailed due to student misbehaviors, they should consider identifying these students and try moving them to another space in the room where they can be successful. Wannarka and Ruhl (2008) said that “classroom arrangement significantly impacts on student behavior, and there is evidence to suggest that it impacts on achievement as well” (p. 1).

Beyond the physical classroom, teachers may also opt to have a flipped classroom. Nouri (2016) described the flipped classroom as having the lecture portion of class being switched with the work that is done at home. This allows for more effective use of the class time and paves the way for more interactive activities to be done in class. Some of the advantages of the flipped classroom are that students can learn at their own pace by watching the lessons at home; class time is essentially freed up for more effective and creative learning activities and teachers have more opportunities to interact and assess student learning (Nouri, 2016). There are also disadvantages to the flipped model, such as access to learning technologies and equity in teaching that must be addressed when using the flipped model.

Math stations are also a classroom style that can help improve student learning. Andreassen and Hunt (2012) described in their article how math stations can help address rising diversity in the student populations with respect to their disability status, language needs, ethnicities, and learning styles. This is because with math stations, it becomes possible for teachers to give their students more than one form of practice or assessment (Andreassen & Hunt, 2012). This means students have more control over the pace of their learning and the teacher can easily see where each student is just by glancing at the room. This classroom style may lack the learning experiences that students gain from large group instruction and discussions, but there are merits to this style. The teacher can easily move from station to station and aid students in their learning. Students may be less likely to be left behind because each student moves at their own pace between the stations. This style also seems to be more work oriented because the students will be at different points of learning so creating opportunities for rich conversations can be difficult during these math stations. Perhaps whole group or small group conversations can happen once the entire class has completed a round of math stations.

More relevant than ever, the online learning classroom can be an option that both teachers and students can choose. In a world of increasing awareness of diverse learners, combined with the increased access to the internet and learning technologies, quality teachers are also in high demand with online learning platforms. Krauthamer (2020) explained in her article how the virtual platform has allowed her and her students more flexibility with learning. The online platform is special because there are aspects that it has which the typical physical classroom lacks. But on the flipside, it also lacks qualities and learning experiences that happen in a physical classroom. This could be different in the future as teachers gain more experience with online learning platforms and technologies, but this is largely the responsibility of teachers. Krauthamer (2020) stated the importance of finding ways to promote active learning through workshops and professional development opportunities. As technologies evolve, the possibility of online classrooms becomes easier.

The physical environment of a classroom and a teacher's teaching style greatly influence the activities and learning done in their space. Knowing how to set up a space is important as it allows teachers to understand what activities are possible in their room. Teachers should also be mindful of how they wish to conduct their classroom. With improvements in technology every year, the possibilities and accessibility of online and flipped classrooms increases. Understanding what works best for students will help create a classroom environment that is conducive to learning. Knowing these factors of the physical classroom will help answer the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Classroom Activities

The activities done in a classroom have a large effect on how students learn and absorb information. As the student population increases in diversity, teachers must be aware of classroom activities that are more accessible to a variety of students. This section reviews a variety of activities that teachers can do to promote learning in their classes.

The beginning activities of a class, often called warm-ups, are crucial because they can set the tone for an entire lesson or even entire units. Rinaldi (2014) talked about how these problems should stimulate student thinking through problems that engage their minds as well as help prepare them for lessons. By providing students with these types of problems, teachers also help change their mindsets and ease them into a math thinking mindset. Students may often think of the math classroom as a class focused on following procedures and executing said procedures. To change this view, teachers need to begin treating the math class like a language class (Rinaldi, 2014). The language and syntax used in math are much different from how students normally use English, so having these brain stimulating activities can help students consciously switch to a math thinking mindset (Rinaldi, 2014).

Rinaldi (2014) also highlighted how beginning activities of a class create opportunities for all students to be successful. This can be accomplished in many ways and it is important to create questions that have multiple entry points. There are a variety of forms these activities can take, such as reviewing previous lessons, introducing the next lesson, how the math relates to the real world, brain teasers that are not directly related to the math lesson but promote critical thinking, and so many more. These activities set the tone for pacing and participation of a lesson and should not be overlooked.

Math curriculum often provides students with vague and unrealistic scenarios in which math is applied. To help students see the importance of math, Masek et al. (2017) described how adding arts into science and math curriculum provides authentic scenarios for students to problem solve and critically think about. When looking at the current state of mathematics curriculum in America, it is easy to see how it has failed to include the freeing process of generating scientific knowledge. Especially in the math classroom, students are told to solve equations and numbers with no real relation to the world. This can make students think math is like a sprint to no location. With no real goal in mind other than learning the math , just because, motivation and effort in the math class decreases. Masek et al. (2017) explained how the switch from science, technology, engineering, and mathematics (STEM) curriculum to science, technology, engineering, arts, and mathematics (STEAM) education can help students make connections between the disciplines. This strengthens their understanding of the curriculum beyond the math classroom. Although there is still a lack of research that exists on the effects of STEAM education, the popularity and trend of STEAM education is on the rise. Masek et al. (2017) said that with this growing attention to STEAM, the quality and how teachers implement new STEAM practices are beginning to make sense of this teaching practice.

The expectations teachers place on students in the math classroom are contradicting. It is expected that students know how to handle real-world questions, but it is commonly seen that students are not accustomed to it (Woolcott, 2018). To combat this, finding topics that relate to the students directly is a great way to motivate students. Woolcott (2018) described how to effectively create a curriculum that is relative to students while at the same time meeting standards. In this study, students learn about problem solving through a five-lesson unit with whales being the talking point; this produced very interesting results. Woolcott (2018) concluded that the project was successful in engaging students and teachers. It also connected students with world-class researchers and other special educators that students normally would not connect with during basic mathematical instruction. By stepping away from the normal math curriculum, new learning experiences are created which can strengthen learning beyond the math classroom.

Math talks are classroom activities that are rising in popularity. Cooke and Adams (1998) discuss how students need opportunities in the math classroom to talk. Talking helps students understand their process of learning on a deeper level. It also creates opportunities for students to see different perspectives of a problem and how a problem can be solved in various ways (Cooke & Adams, 1998). Math talks are activities that can happen in both small groups and whole class discussions. The goal is to emphasize the discussion piece of math and the multiple perspectives students and their peers have on a certain topic (Cooke & Adams, 1998). When doing these activities, a sense of community in the classroom is also created because students hear what their peers are thinking and can make connections. The questions and activities during math talks should be accessible by all students and be solved with various methods. Teachers can choose to use these talks to both establish and further strengthen the community in a math classroom. They are also great activities to do as warm-ups as they get students into the mathematical mindset.

When using or creating activities for students, it is important to review it to see if it is accessible to students with learning disabilities. Bishara (2018) explained how an "active teaching approach assumes that a group of learners in class is heterogeneous and recognizes the existing differences among pupils in terms of their personal and academic skills" (p. 2). By using active learning activities in class, the achievement gap can be closed and equity in learning and learning experiences can be achieved. Active learning creates opportunities for student discourse and allows them to become reflective learners through these interactions. These activities require whole class participation to be fully effective and a solid, supportive learning community to be established so learners feel safe. Bishara (2018) stated that, based on existing research, active learning will lead to students' improvement on their self-image as well as their motivation to learn math amongst their peers in special education classes.

Activities in the math classroom do not always revolve around problem solving and critical thinking. There is a certain value to having students take a step back to see what they have accomplished. Kinser-Traut (2019) explained how she used math projects that revolved around answering the questions, why Math? to engage students who had negative previous experiences with mathematics. These types of activities are great because they are accessible to all students. There is no prior knowledge requirement and students have relative freedom with where, what, and how they conduct research. It is also important to scaffold these lessons, so students know there is structure and a purpose to the work they are doing. This is not a simple activity to fill up time, it is a valuable learning experience for students and it can help spark interest and motivation for students. Kinser-Traut (2019) described the process once students finish researching. She has students share with a peer what their finders were and then they come together as a whole group to share ideas and findings. This think, pair, share process is very effective and can be used in standard math activities as well. By having students share their thoughts and findings, they can relate with each other. This further strengthens the learning community and can set the class up for success in the future with group and whole class activities (Kinser-Traut, 2019).

When creating curriculum and activities for students, teachers must understand the effects activities have on students. Having a balance of practice, critical thinking, and discussion based problems is important as it helps develop students' short-term and long-term learning. It also gives students an opportunity to reflect on their learning. These activities that teachers provide for their students are directly related to providing students with opportunities to engage with their peers and aids in answering the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Types of Learners

Cassi and Dani (2016) emphasized the importance of early math experiences in a young children's development because it is essential for helping them develop number knowledge which leads to a strong base mathematical thinking. Educators must be aware their students are coming from diverse backgrounds and it is very likely the parents of their students are not comfortable teaching and discussing math at home. Therefore, it is important to be mindful when creating activities in the classroom.

Diversity

Social diversity in a classroom gives students unique opportunities to look at math from alternative viewpoints (Lacina & Griffith, 2018). Because students come from varying backgrounds, their approaches to problems will be different. Some students may understand a direct approach to solving a problem, while another student may take a route that is less common but produces the same answer. Diversity in the classroom also creates unique interactions between peers and allows students to find ways to agree or disagree on topics with civility (Lacina & Griffith, 2018). The classroom should be a safe and low risk environment in which students can learn how to agree and disagree. By providing students with these opportunities, the chances of exemplifying civil behaviors beyond the classroom can increase. Lacina and Griffith (2018) conclude that having diverse learners enriches the learning experience for all students in the classroom.

English Language Learners

Student diversity continues to rise, and along with this, the number of English language learners (ELLs) rises as well. ELL students have varying levels of math abilities and many may face the obstacle of comprehension (Orosco et al., 2013). Mathematics content is especially challenging because it requires content knowledge as well as knowledge in the English language. Students are expected to be able to read, write, and comprehend when they enter a math classroom. ELL students can struggle in the math classroom because they are still developing their skills. Orosco et al. (2013) explained how these challenges can stem from comprehending things like irrelevant numerical information, vocabulary, and the math language of word problems. It is common for teachers, books, and tests to ask students word problems that are long and full of math jargon. This practice is unfair to ELL students as they are still developing their comprehension of the English language. Because of this, it becomes difficult for teachers to understand where their ELL students are with understanding the math content. It is important to be aware of whether the content and curriculum in a classroom is accessible and equitable for ELL students.

In a study by Aldugon et al. (2020), they explored whether gestures during math instruction specifically benefit learners with high visuospatial working memory capacity (WMC). In their findings, they discovered a positive relationship between visuospatial WMC and math learning when gesture was present. These findings support the importance of diversifying methods of information transfer during lessons. Whether it is a lecture or an activity, providing students with more than one way to understand and see a topic explained will increase the chances of student understanding of the content.

Immigrant Students

Often grouped with ELLs, immigrants are another group of learners that add diversity to a classroom. When immigrant children arrive in a new country, teachers need to be aware of how they can best transition the student into their classroom. Things like what culture they are coming from and whether they received schooling in their home country are important in the process of giving the student a way to bridge the connection between their initial situation with the present (Aberu & Presmeg, 2001). Having a well-established learning community can help immigrant students transition easier. By creating a supportive and understanding classroom environment, immigrant students will feel safe when taking risks with expressing their ideas and personality.

In relation to EL students, Callahan, Humphries, and Buontempo (2021) seeked to find if a students' math performance and achievement is a product of not only their instructional experiences, but also their math placement. To find the answer to this, they looked at data from the Education Longitudinal Study, which consisted of approximately 15,000 high school sophomores divided amongst 750 schools between the years of 2001-2002. They sent student surveys and transcripts were collected. They only sampled students who were enrolled in math for grades nine and ten as previous math performance was also a factor. In this study, math performance was the dependent variable while independent variables were participation in student-led math discussion, linguistic status, and sociodemographic controls such as student and family background and tenth-grade math placement. In their findings, they found that native English speakers showed significantly higher math GPAs compared to bilingual and EL students. They also found that 52% of bilingual EL students were placed in below-grade level math. Bilingual EL students reported higher participation in student-led discussions because they were placed in EL focused math classes which had emphasis on learning through discourse (Callahan et al., 2021).

Teachers must be mindful of the diverse learners in their space. Being aware of what students' needs are will allow them to better modify lessons so all students' learning needs are accommodated for. This creates a learning environment that is academically safe and accessible and helps answer the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Conversations in the Classroom

Jennings and Greenberg (2009) stated that over the past decade, there has been an increase in the need for students to improve not only academically but also socially-emotionally. Skills like conflict resolution, stress management, and awareness of others can be practiced through interactions with peers in the classroom. Practicing safe and respectful behaviors in a controlled environment helps create an academically safe environment where students can support each other and develop new relationships (Jennings & Greenberg, 2009). Teachers can also create curriculums that give students unique opportunities and experiences to practice their social skills. By creating controlled tensions, such as discussions on the solution of a problem, students can learn how to safely resolve conflicts and cooperate to find an understanding of each other (Jennings & Greenberg, 2009). In most math classrooms, students are not given opportunities to speak their mind on a problem. When a correct answer is given, teachers may often move on to the next problem with very little regard to what other thoughts or methods students may have used.

Bennet (2010) highlighted how it can be especially challenging to get students to discuss math with each other and in the whole class setting. This is because students fear embarrassment and seek social acceptance by their peers. The students who are more prepared and understand the material faster gain the opportunities to speak because they know they have less to lose from previous experiences. This leaves the students who are unsure of their thoughts and ideas to be left behind. Perpetuating this system only creates a larger gap between successful and struggling students. Adding diverse learners into the mix and the gap furthers even more. It is up to the teachers to create, foster, and facilitate lessons that promote equitable opportunities to discuss mathematics (Bennet, 2010).

Teachers should also participate in developing their social-emotional skills with students. When teachers lack the skills to manage the social and emotional challenge of their classroom they can burn out and be at risk of dropping out of the teacher workforce (Jennings & Greenberg, 2009). By practicing these activities with students, teachers are more likely to understand how to communicate with students on a social and emotional level. Feeling empathy for students and creating connections with them help foster a learning community that respects one another. Without these aspects of a classroom, undesired behaviors and student interactions can derail learning.

Math Discourse

It is a daunting task for teachers to successfully implement a new mathematics curriculum as it requires a significant change from the traditional teaching styles seen today in math classrooms (Hufferd-Ackles et al., 2004). It also requires a math discourse community to be developed and sustained. Hufferd-Ackles et al. (2004) described the math-talk learning community as a classroom in which the teacher and students use discourse to support and enhance mathematical learning for all students. An example of this would be a teacher launching a lesson and then letting the student lead the conversations. If students were to get stuck or the conversations were to stop, the teacher’s role would be to redirect the conversation. The primary goal of these communities is to teach students how to be reflective learners. When students are conscious of their learning, they better absorb the information (Hufferd-Ackles et al., 2004). By having students discuss their mathematical thinking, they also gain alternate perspectives of how to approach problems. Math-talk learning communities also benefit the teacher. When students effectively communicate their thoughts, teachers gain a deeper understanding of where students are in their learning and understand the content. Using this, teachers can choose to reel back lessons or keep moving forward. Hufferd-Ackles et al. (2004) concluded that math-talk learning communities can be used, even with many ELLs. The results may vary but it goes to show how effective it can be for creating an academically safe classroom that is accessible for diverse learners.

In research by Callahan et al. (2021), they find that student-led discussions positively affected math performance for all students across all course levels. They also found that, given the disproportionate number of EL students in lower-level math, having student-led discussions was not enough to achieve equity in the classroom. There are things teachers must do beyond facilitating these discussions. It is important to know that these discussions are a powerful tool to use in the classroom but are not the only thing a teacher should do when trying to achieve equity in the school. Callahan et al. (2021) emphasizes how bilingual EL students are significantly more likely to be placed in a math class that is below their grade level. By being aware of this, teachers can find ways to accommodate students to ensure they are holding all their students to high expectations.

Kakas (1991) explained the importance of two types of communications in the art classroom. The first is communication structured by teachers and includes activities like small group projects, think-pair-share activities, and peer-tutoring activities. The second is spontaneous peer interaction, which are unplanned instances in which students exchange information. The math classroom is typically filled with the first form of communication where teachers communicate with students on things related to the lesson, praise on work, lesson concepts, and evaluative comments. The second is student initiated and often includes things related to comments on the content of their picture, noticing one's ability, and requests for materials (Kakas, 1991). Although this was done in an art classroom, the concepts can also be applied to other classrooms. Teacher driven communication is an external force that drives student learning. This is heavily used in classrooms and teachers often set the pace of lessons using these forms of communication. Student driven communication is internally driven and shows a student's motivation. Finding a balance of the two is important in the classroom and understanding the importance of both can help with this process.

Math discussions improve the math classroom in many ways. By creating these opportunities, students gain unique learning experiences that benefit the entire learning community. Teachers must be knowledgeable when facilitating math discussions in order to give students sufficient time to reflect on their learning. Ensuring that the conversations are student-led is another important aspect as teacher-led conversations don't allow opportunities for students to interact with their peers. By adding math discussions to the curriculum, students' learning experience will be enhanced. These discussions are crucial as they are the central theme of the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Mathematical Maturity

Mathematical maturity can be connected to students' sense of motivation to learn. Bishira (2018) said that motivation is important to children of all ages and is divided into two categories, internal and external motivation. Internal motivation stems from things like curiosity, experimentation, and self-image. This is an aspect of learning that many teachers try to cultivate through external motivation. External motivations include but are not limited to the need for social recognition, support from a teacher, and feedback from others (Bishira, 2018).

In a study by Kaskens et al. (2020), children's math self-concept, math self-efficacy, math anxiety, and teacher competencies were researched to see how they impacted math development. Previous research of the development of children's math skills have focused more on a child's cognitive ability and less on their self-perceptions, math self-efficacy, and math anxiety. It has been shown that there is a direct correlation between a student's feelings towards mathematics and their math achievement. Students who performed well in math had positive math self-concepts and math self-efficacy. Students with poorer math skills were more likely to have a correlation with math anxiety. Finding opportunities for students to safely develop their math self-concept and math self-efficacy is important in math classes. No single task can lead students to be fully developed, but by providing students with an academically safe environment, they are more likely to gain positive attitudes towards mathematics.

Math Self-Beliefs

Kaskens et al. (2020) also described how math development can be connected to a child's math self-beliefs. Math self-beliefs are divided into three categories: math self-concept, math self-belief, and math anxiety. Math self-concept is how a student sees their competence in the classroom. Math self-efficacy is a student's own belief of whether they can answer a question. Math anxiety is an emotion which students feel when faced with challenging tasks they are unfamiliar with. It has been found that math anxiety has a negative relationship with math achievement. When a student with math anxiety faces a question or material that gives them anxiety, they are more likely to find ways to avoid it. Because of this, it is common to see classrooms with many students below grade level to experience low participation from students. Teachers must use this knowledge to their advantage. By understanding why students are feeling anxious, teachers can scaffold lessons to better suit the needs of their students. It is important to note that if a student has a positive math self-concept, it does not automatically mean they will also have positive math self-efficacy and no math anxiety (Kaskens et al., 2020).

In a study by Legette and Kurtz-Costes (2020), the relationship between math tracks and early adolescents' math self-concept was analyzed. Self-concept in academic situations is the perceptions of one's academic ability. This is shaped through their beliefs and how they compare themselves to their peers, but can also include how they believe the teacher perceives an entire class. Tracking is the process of setting up students based on perceptions of their academic abilities. It is common for tracking to begin in middle school, which is also a crucial time psychologically for middle school students as they are adjusting to a new school environment with multiple teachers and new peers (Legette & Kurtz-Costes, 2020). During this time, students start to develop their sense of self beyond the classroom. Cliques are formed based on student self-concepts and this research examines whether tracking has a relationship to student's self-concept. Legette and Kurtz-Costes (2020) explain how tracking is established through students' performance on standardized tests and prior academic achievements. The higher tracks often gain the title of honors, accelerated, or advanced. It is suggested that tracking would be an effective way to divide students based on their varying cognitive abilities. Doing this could allow schools to challenge students on the high track while not letting lower track students fall behind. But by putting students on tracks, students gain external information about what others think about their cognitive abilities. This, combined with the crucial stage they are in as adolescents, can create a relationship between their self-concept and academic abilities (Legette & Kurtz-Costes, 2020). Legette and Kurtz-Costes noted that their findings were consistent with other recent large-scale studies. What they found was that students on the higher track did have a higher self-concept compared to students on the lower track (Legette & Kurtz-Costes, 2020).

This can also be further perpetuated in competitive schools in which students are commonly reminded of where they are placed. It is important to note that in this study, teachers' grading patterns or curriculum differences between higher and lower track classes were not considered. This means that it is still possible to create a curriculum in a school that uses tracking to help students develop a positive self-concept in the math classroom. Because this study was only done in a math classroom, it cannot be assumed that the same results would be reproduced in an English, science, or history class. Schools can choose what subjects they track, and it is very possible that schools with high amounts of tracking can have high correlation with students' self-concept. Students are not blind to the school climate and often create the climate amongst themselves. Teachers need to be mindful when creating curriculum, so that it promotes a healthy and positive self-concept (Legette & Kurtz-Costes, 2020).

Classroom Stereotypes

Stereotypes are another factor in classrooms that can harm a students' mathematical maturity and self-concept. Keller and Dauenheimer (2003) took a closer look at the mechanisms that may cause gender differences in math performances and stereotype threat theory (STT). STT assumes that the negative stereotypes placed on stereotyped groups adds pressure which then undermine the performance of the group. To find out if there was a relationship between math performance and stereotype threats, students were given a test under normal circumstances. The participants were randomly divided into two groups and were administered a test by a male, the classes were mixed gender. Group one received a test that stated the questions on the test were known to not produce gender differences. Group two received the same test but were told that the questions were known to produce gender differences. The test had 26 questions, 19 from the Third International Mathematics and Science study, and 7 from math textbooks. Of the questions, 22 were open ended and 4 were multiple choices. After the test, students were asked to rate their anxiety on a scale of 1 to 7. In their findings, they found that women in the first group, where there was assumed no gender stereotype threat, attempted significantly more questions than women in the second group. The mean scores of the women in group two were found to be significantly lower than the mean for women in group one. This early finding suggests that stereotypes did have an influence on the motivation and performance of stereotyped groups (Keller & Dauenheimer, 2003). It is also important to note that participants were not required to have a high interest in math to participate in the experiment. With the results, it meant that STT extended beyond a class with high interest in the topic and could even harm lower-level classrooms. Keller and Dauenheimer emphasized how these results could happen outside of a controlled setting such as a high school classroom. Teachers must be aware of this and create curriculum that does not hold students to stereotypes.

Growth Mindset

The growth mindset is the belief that attributes such as intelligence, athletic ability, and other skills are not static meaning they can change and grow through time and hard work (Boaler & Dweck, 2015). Contrasting the growth mindset is the fixed mindset, which is the belief that these attributes are fixed and cannot be changed through hard work. (Burnette et al., 2020). In this study, the connection between growth mindset and student self-efficacy was examined. The growth mindset implies that everyone can become successful at something if they put forth the effort. Teaching this to students can be very helpful, especially in classrooms where the majority of students are below grade level. Burnette et al. says their primary hypothesis is "Growth mindset messaging, relative to an attention-matched control, increases entrepreneurial self-efficacy" (Burnette et al., 2020). They integrated and applied study-related materials into the curriculum, which students accessed through online modules. In their findings, they confirm that using growth mindset type interventions increases entrepreneurial self-efficacy as well as improved persistence on challenging academic tasks. By showing students that their knowledge is not fixed, they begin to break free of the track and stereotypes set onto them by society. This is a crucial step in the classroom and can help foster a healthy learning environment (Burnette et al., 2020).

Student learning goes beyond following math procedures. Teachers must also present students with opportunities to develop their mathematical mindset and math self-belief. These aspects are a central theme of creating curriculum focused on student learning through discourse and answers the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Conclusion

It can be a daunting task for teachers to modernize their curriculum so it is more responsive and equitable for students. The articles reviewed above highlight important aspects of the classroom that teachers must be knowledgeable of when creating a student centered curriculum that creates opportunities for student-student discourse and student-led discussions. Diverse learners must also be accounted for as well as the various subgroups within diverse learners. Many articles noted the increasing diversity of the student population and the need for curriculum to meet their needs. The literature reviewed above highlights various factors that must be considered when answering the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Chapter Three takes the concepts from chapter two to create a unit which promotes student-to-student discourse while still meeting state standards. It provides teachers with a student centered Quadratics lesson and includes various assessments, activities, and projects. There are also sections in the unit for teachers to use for reflection.

CHAPTER THREE

Project Description

Introduction

It is important to get students to talk more in math classrooms. Teachers understand this but when they search for resources to gain inspiration and ideas, the options are lacking and often cost money. Developing curriculum during a school year is challenging and messy because teachers must balance grading, classroom preparations, meetings, their personal lives, and so many other aspects of teaching. As a result, the design process falls short, often causing teachers to feel pressure and revert to previous methods they are familiar with. Taking time to create a curriculum ensures a quality product that can be implemented. I also created this curriculum so I could use it during the following school year. This helped with my first full year of teaching high school students. Having structure and plans in place helped improve my students' learning experience.

Chapter Three covers the process and reasons behind each part of the curriculum. This curriculum answers the capstone question, *how can teachers increase student-student discourse in the math classroom?* It also includes sections to aid with facilitating lessons, classroom setup, and classroom management. These factors especially affect student centered lessons and the skills required to effectively use this curriculum take time to develop.

Project Description

I answered the capstone question by creating a unit long curriculum. The curriculum focused on learning through student-student discourse and covered the

Quadratic Equation. It met Minnesota state standards 9.2.1.5 and 9.2.1.6 (Appendix A). The way students learned and were assessed was strictly through participation in daily lessons. There was no standard summative assessment created because doing so would cause students to stress more on the test than discussions. Math is often seen as an independent class but in the real world, mathematicians work with a variety of other professions. It was important to model this in the math classroom because it showed students how math is more than numbers and problem solving. Masek et al. (2017) emphasized the importance of creating authentic real life examples of math for students. Doing so enhances student understanding and allows them to make connections across disciplines (Masek et al., 2017).

The curriculum involves many moving parts that must be implemented in order to make it effective. There is the unit summary which provides the teacher with the main learning objectives of the unit (Appendix B). Teacher instructions are also included because of the high level of facilitation required with this curriculum (Appendix C). Students will be given a packet which provides the activities they will do with their groups (Appendix D). To lead the classroom, the teacher will use a powerpoint to help with pacing and whole group discussions (Appendix E). Lastly there are suggested seating arrangements provided in order to make facilitating group work easier (Appendix G).

The main activities that students are tasked with involve Think-Pair-Share activities and group discussions. After group discussions, most lessons have large group discussions where groups can share their findings with the entire class. Large group discussions can be difficult to facilitate, especially when class sizes go above 30 students, so teachers have the option to break students up into smaller groups so every student can have an opportunity to share their thoughts. Think-Pair-Share activities are also strongly used as they provide opportunities for students to quickly share their thoughts with a classmate while allowing teachers to gauge classroom understanding (Kaddoura, 2013). Students write down their thoughts and findings from the activities in the student packet (Appendix D).

Seating arrangements are included as part of the materials for the unit (Appendix G). Making sure students could fluidly transition into partner and group activities improved the efficiency of lessons. There was also a section to help teachers ensure their groupings are well-mixed. The mixed level groupings created opportunities for diverse conversations and improved the learning community. In the middle of the unit there was a reminder for teachers to mix up seating arrangements. This practice can be easily forgotten, so it was important to include a reminder for teachers.

Conversations in Math Classrooms

If one were to walk into any random math class in America, they would most likely see the teacher giving instructions or students having quiet work time. American schools are obsessed with quiet work time and it is especially used in math classes. Students are rarely given the opportunity to have actual conversations. In science classes, students are commonly seen discussing experiments and explaining what they think happened. In English classes, students share their thoughts and opinions on books they have read. In history classes, discussions about why events were impactful happen often. But in the math classroom, it is rare for students to talk unless they are answering a teacher’s question. This is a common experience and it continues today.

The “I ask, you answer” format in math does not support diverse learners and fosters an academically unsafe environment (Fennema & Romberg, 1999, p. 26). Every question the teacher asks is high risk, even if the teacher does not mean it to be. This is because the pace of the lesson is set by the teacher and any stops or slow downs are determined by the students. Answer a question right, and the lesson moves on. Answer a question wrong, and the lesson stops, as does the additional feeling of embarrassment in front of the entire class. Teachers need to understand that students are still developing their self esteem, and to answer questions in front of the class is a large risk for them (Brophy, 2004). Many students resort to not answering unless they are called on and students who always know the answer begin to set the pace of learning for everyone else. It is no easy task to realize which students are always answering questions and which are not. But it is something teachers must do if they wish to create an academically safe learning environment.

Conversations in the math classroom typically happen in two different forms, whole class and small group. To support an academically safe classroom, it is crucial to be aware of the appropriate questions to ask students during the three different forms of conversations.

Teachers typically use the “I do, you do” format rather than having the students drive the conversations (Fennema & Romberg, 1999, p. 13). Doing so does not create a sense of community in the classroom and further divides students. Teachers should instead focus on asking open ended questions that promote discussion among students (Fennema & Romberg, 1999, p. 15).

Whole class discussions are also great for sharing the thoughts and ideas discussed during paired sharing. Students are presented with a low-risk environment in which there is no definitive right or wrong answer. This allows them to express themselves and connect with other students. Being aware of these factors can greatly improve the quality and quantity of whole class conversations.

Paired sharing sessions are another great tool to use when trying to implement opportunities for conversations in the math classroom. Using paired sharing allows students to problem solve and discuss with a partner in a relatively low risk environment. During this time, students can easily ask their partner for help or both students can request help from the teacher. Paired sharing is also especially good at increasing the number of unique social interactions among students (Shih & Reynolds, 2015). With a little bit of work and awareness, teachers can easily pair up students who work well together or pair up students who will benefit one another. Paired sharing also allows for diverse groupings. Students who do not interact with each other on a usual basis will have to work together and learn more about each other in the process. This can further enhance the classroom's sense of community and provide a more academically safe environment (Kaddoura, 2013).

Theories

Masek et al. (2017) talked about how in mathematics, students are told to solve problems with no real relation to the real world. This repetitive action leads to many students feeling they are learning things of very little importance in math. By creating a curriculum where students can discuss their learnings and make connections with their peers, the content becomes more relatable. Students crave relatability because they want to understand how concepts they learn apply in the real world. Knowing that there is meaning and use to what they are learning helps increase student motivation and participation (Woolcott, 2018).

Callahan et al. (2021) also found that student-led discussions had a positive effect on math performance for all students across all course levels. Lacina and Griffith (2018) expand on this and explain how diversity in classrooms creates unique opportunities for students to see math from different perspectives. It also gives them a safe environment to agree and disagree on topics which further enriches the learning experience for all students (Lacina & Griffith, 2018).

Setting

The curriculum was implemented in a high school with a diverse student population. Around 35 percent of students were Black, 35 percent Asian, 20 percent Latinx, five percent White, and five percent other. Many students were English language learners with varying levels of proficiency. The classroom sizes at the school ranged from 25 to 37 students. It was common for the class sizes to be too large for the physical classroom. The location of the school was in the suburbs just outside the urban city and the majority of families were below middle class for income. The school had around 70 to 90 percent of students who were on free or reduced lunch. Staff were mainly White educators and there were few teachers of color.

Participants

The students and teachers were the participants for this curriculum. Students had the role of receiving the lesson and providing teachers with important feedback. Teachers gave the lessons and were also responsible for practicing reflection at the end of each lesson. Close monitoring of student progress and participation was also important in order to make sure all students had equitable opportunities to speak and participate. To help with this, a participation spreadsheet is included in the lesson materials (Appendix F). It was also suggested that teachers ask for observations from their colleagues as it could provide a wider perspective on how the new curriculum was doing.

During the development process it was important to be aware of diverse learners in the classroom. Students were from backgrounds with English as their second language and it was crucial to provide equitable speaking opportunities during student-student discourse activities. Knowing the appropriate accommodations allowed ELLs to focus on the concepts of math rather than getting caught up on things like irrelevant numerical information, vocabulary, and the language used in math word problems. (Orosco et al., 2013).

Development Timeline

The first and most important step in the development of this curriculum was to determine the standards and assessments it covered before the creation of any classroom activities. This ensured that each activity developed had a purpose. Students can easily see when an activity is done just to take up time, teachers must avoid having time filling activities at all costs. Doing this also helped teachers clearly see the goals and standards each activity covered at a glance. Organization was key to creating and implementing a new curriculum so this process was not taken lightly. The first two weeks were time for teachers to determine what goals and standards will be covered during the unit.

It is ideal to begin lesson planning during the summer season when school is out of session. Having ample time to focus solely on the curriculum ensured that quality lessons and activities would be made. Lessons focused on creating authentic opportunities for student-student discourse. Conversations about the thinking behind mathematics were a recurring activity and focal point for all lessons. Having students learn how to vocalize their thoughts was an important practice and it was expected that every student would have equitable opportunities to do so.

Students were also expected to problem solve in pairs or groups. Having these activities created unique opportunities for students to share their thoughts with their peers. Students also got to observe and experience the process of solving practical and real world problems with the math they learned. The problems posed in the group work were more challenging than what they would be used to in a typical classroom. This was in order to create chances for students to struggle with math concepts in a safe environment. There were groups of students that did not come to a solution and it was important for the teacher to emphasize that it was okay and normal for this to happen. It is important to highlight this phenomenon because math classrooms often put too much emphasis on the answer and stressing this does not represent real mathematics.The next five to seven weeks were used to create, adjust, and reflect on classroom activities. Researching activities that other teachers have used which promote student-student discourse can help alleviate the stress of having to develop a large amount of new activities. This time was also used to discover new technologies to help in the creation of handouts and directions. Knowing multiple softwares to create assignments is beneficial as each software provides unique features that can work to the users advantage. Within the curriculum guide are links to free software that teachers can access.

The last three to four weeks focused on finalizing and touching up any parts of the project. Having time to reflect on classroom activities is important because activities that initially seemed like a good fit may change during the revision process. Revisiting activity handouts was also done during this time. Sloppy and hard to follow handouts make activities difficult to facilitate because students can struggle with finding key points and directions within the handout. Making sure that all handouts, accommodations, and directions are easy to follow will help with the fluidity while teaching these lessons.

Assessing Effectiveness

To assess effectiveness, questions were created in the closure portion of lessons for students to answer. This also served as an exit ticket. Getting feedback from students was crucial as they are the ones who are receiving the lessons. Knowing how they feel about a discourse styled learning can help the teacher make adjustments on the fly. Any concerns of students can also be addressed through these questions. The teacher will have to be meticulous and observant when teaching this discourse focused unit.

Summary

Students learn best through discourse with their peers. Rather than creating random opportunities to talk about math, teachers should create entire lessons that emphasize learning through student-student discourse. By doing this, teachers can better accommodate diverse learners as random opportunities to talk about math leaves many students lost and unsure. Having strong lesson plans also allow the teacher to better facilitate lessons because they will be more prepared to answer questions and redirect the classroom if lessons are derailed. Chapter Four is the culmination of the theories, ideas, and concepts covered in Chapters Two and Three. It contains a curriculum for Quadratics and emphasizes learning through student-student discourse. There is also a section that reflects on the effectiveness of the new curriculum and determines whether it answers the capstone question: *How can teachers increase student-student discourse in math classrooms?*

CHAPTER FOUR

Reflection

Introduction

For my capstone project, I chose to answer the question: *How can teachers increase student-student discourse in math classrooms?* There is a lack of readily available lessons for math teachers that focus on learning through student-student discourse. To answer the capstone project, I created a quadratics curriculum that emphasized learning through student-student discourse and conversations. There are many moving parts to this curriculum that teachers and students must be aware of. It is not a standard mathematics curriculum that teaches students through examples and repetition. Instead, students will be given many opportunities to work and learn with their peers.

Personal Self-Reflection

As I complete my Masters, it feels like I have only started my journey in learning how to change the curriculum of the traditional math classroom. Thinking back about my own experiences in math, I only remember listening and watching teachers go through mathematical procedures. There were rarely any opportunities to learn from mistakes in a low risk environment. Group work was merely grouping students up to independently work on homework. I hope to change the format of the traditional math classroom for future students through the creation of new curriculums. It will undoubtedly feel different for both teachers and students because of the change of expectations but this process is necessary in order to advance and improve the current mathematics curriculum.

This curriculum was aimed at creating opportunities for students to make mistakes and learn from those mistakes in a safe environment. In the typical math classroom, there are few opportunities for students to make mistakes and not be punished in some way. Learning through exploration is an aspect of math that is lost in the traditional classroom. My hope is that with this new curriculum, students will take back their learning and learn how to be explorers in the math classroom.

Review of Literature

The literature that was reviewed in Chapter Two set the foundation for a lot of the curriculum design. The main topics that were covered were classroom styles, classroom activities, types of learners, conversations in the classroom, and mathematical maturity. I will reflect on how each topic played a crucial role in developing a curriculum focused on teaching and learning through student-student discourse.

Classroom Styles

The way a classroom is set-up physically largely affects the teaching styles and possible student activities. Brophy (2004) emphasized the importance of satisfying lower levels of Maslow's Hierarchy of needs before higher needs can become operational. The first two levels of needs are physiological needs and safety needs (Brophy, 2004). Making sure students feel that they are in a safe environment can improve their learning experiences. Seating arrangements are also important because of the advantages and disadvantages they can have (Bolden et al., 2008). It was important to be aware of these factors when designing the curriculum because of the emphasis placed on learning through student-student discourse. Having students already seated in their groups means there is no time wasted in transitioning into groups.

The type of classroom that is used is also an important factor. Before the curriculum was created, it was determined that it would be designed for a face-to-face classroom. There are many types of classroom formats that can be considered and for this curriculum, face-to-face was chosen because of simplicity. It is very possible that in the future, the curriculum will be adjusted for the flipped classroom. In the flipped classroom, lecture and classwork are switched which gives students more time to work with each other (Nouri, 2016). Because the curriculum is already student-student discourse focused, having a flipped classroom may not serve a purpose. The online classroom is a relatively new setting for students but provides many benefits such as high accessibility for students (Krauthamer, 2020). This format was not considered during the creation of the curriculum but can be used. If it is used, teachers must find workshops and technologies that promote active learning (Krauthamer, 2020).

Classroom Activities

The research of Rinaldi (2014) was very impactful in the development of the curriculum. Warm-up activities are included everyday because it is important for students to have low risk opportunities to change their mind set as they come in from other settings (Rinaldi, 2014). The warm-up activities created are related to the bulk portion of the lesson and provide opportunities for students to successfully take risks. Some of the warm-up activities will also involve math talks. Cooke and Adams (1998) explained how math talks create a sense of community in the classroom. Creating a positive sense of community improves the effectiveness of this curriculum because it emphasizes the importance of discussions in math and students the multiple perspectives of their peers (Cook & Adams, 1998).

The closure activities in the curriculum were carefully created with guidance from Kinser-Traut. It was important to have closures that did not involve problem solving or critical thinking because the bulk portion of the lesson is already focused on those skills. Kinser-Traut (2019) explained how there is value to having students take a step back to see what they have accomplished. Having this opportunity for reflection is important and different from a typical math curriculum. Reflection is usually something that is done at the end of a unit or year but taking time to slow down in between lessons can help students feel less overwhelmed.

Types of Learners

Diverse learners were a focal point during the development of the curriculum. The work of Lacina and Griffith (2018) supports having diverse learners in the classroom because it enriches learning for all students. This was important because student-student discourse is how students are learning. Having students see the different perspectives of their peers can enhance the learning experience and create a stronger sense of community. During these interactions between students, it is the responsibility of the teacher to ensure that students have a safe environment where peers can have civil discussions about the topic (Lacina & Griffith, 2018).

English language learners were also considered throughout the curriculum development process. There is a larger emphasis on discussion rather than reading in the lessons. That is because of the findings of Orosco et al. (2013), which explained how ELL students can struggle in a math classroom because they are still developing their skills in reading, writing, and comprehension. The daily discovery activities are heavily based on open discussions and there is very little reading that is required by students.

This Gives more time for students to think about the mathematical concepts and also means the teacher may spend less time answering questions related to comprehension of the math language used.

Conversations in the Classroom

The findings of Jennings and Greenberg are just one of the many reasons why this curriculum was created. There has been an increase in the demand for students to learn social-emotional skills in schools (Jennings & Greenberg, 2009). By having students talk about math, they are given opportunities to develop their social skills. There is a sense of challenge that is always present in any classroom when it comes to discussions and Bennet (2010) discussed how it is up to the teacher to create, foster, and facilitate lessons that give students equitable opportunities to talk about mathematics.

Huffered-Ackles et al. (2004) also highlighted how conversations in the classroom help students become reflective learners and create a Math-talk learning community. Giving students an opportunity to reflect on their learning makes them more conscious of it and allows them to better absorb new information (Huffered-Ackles et al., 2004). Huffered-Ackles et al. (2004) concluded that Math-talk learning communities are also beneficial for ELLs and teachers. ELLs are given opportunities to communicate their understanding and teachers are then able to gain a deeper understanding of where their students are in learning the content (Hufferd-Ackles et al., 2004).

Mathematical Maturity

The main reason why this curriculum is based on learning through student-student discourse is so students can develop their mathematical maturity. Kaskens et al. (2020) described how a student's development in math is connected to their math self-belief. The students this curriculum was designed for came from diverse backgrounds and it is important to provide them all with opportunities to develop their math self-belief. Doing so further improves their chances of gaining a positive attitude towards mathematics (Kaskens et al, 2020).

Along with the mathematical maturity, the curriculum was also designed to help teach students the growth mindset. Burnette et al. (2020) explained how the growth mindset implies that everyone can become successful at something so long as they put effort into it. The growth mindset is important because there are challenging tasks in the curriculum for students to attempt and persistence during these activities is key to the learning process.

Limitations

There are many limitations of this curriculum as there are with any newly developed curriculums. The following section will be stating just a few of the major limitations of the curriculum. Finding ways to thoughtfully assess the effectiveness of the curriculum will take time. It is important for teachers who implement this curriculum to find other peers and professionals who can observe how they are doing in facilitating lessons. With constructive feedback, the curriculum can be changed to better fit the needs of future students.

Another limitation is the large number of moving parts in the curriculum compared to a standard mathematics curriculum. Rather than the common, I do, we do, you do format of a typical math lesson, the lessons in this newly developed curriculum involves high levels of facilitation from the teacher. Students are encouraged to think slowly and deeply rather than quickly so they can truly understand the concepts introduced. There is a high chance that students will not be familiar with this type of teaching and learning process because they are used to a traditional format. It is important for the teacher to persevere knowing that students need time to adjust to the discourse focused curriculum.

Lastly, a possible limitation to the curriculum is where it is implemented. The curriculum does not have a section for a formal summative assessment like a traditional math unit. Instead, there is a large focus on student participation and effort. This was done in hopes to emphasize the importance of student participation. Depending on where a teacher works and the requirements for formative and summative assessments, a standard summative assessment may be needed to assess individual understanding.

Next Steps for Research

This section discusses the next steps to further develop the curriculum for students. Exit tickets received from students should always be kept, documented, and read through thoroughly. Student feedback is the most important feedback because they can offer unique perspectives on how the curriculum is being delivered. Getting feedback on subjects like pacing, group sizes, flow, and clarity of information is crucial to improving the curriculum.

Additionally, it is important to be mindful of the diversifying student population. By knowing the demographics of incoming students, activities can be modified to best fit their needs. It is also important to research new accommodations for students that can work in a discourse community. Making sure all students have equitable opportunities to speak is crucial to the effectiveness and success of this curriculum.

Implementation Plan

The primary plan is to implement this curriculum December 2022 to my Advanced Algebra class of tenth graders. As of now my school is planning to go back to in-person learning but with the current situation of the COVID-19 pandemic, I am unsure that my school will be able to remain in in-person learning the entire school year. Students will also be coming back from their first full year of distance learning and at the moment my colleagues and I are more concerned about trying to find out ways to effectively catch students up. Many classes were not able to cover their entire curriculum and it is expected that most of my students for the 2021 year will be coming in with large gaps of knowledge. Therefore, I plan to implement the curriculum in the following year with the hopes that students have been caught up on missing content. If not then some parts may need to be modified to fit students needs.

While the curriculum is implemented, I will be taking notes about what parts need improvement according to the needs of students. New curriculums are never perfect and I am aware it will require much revision before reaching its full potential. With that in mind, I know I will be able to persevere through the process of reflection and revision. I plan to ask for feedback from my colleagues who all have been teaching for many years and fully expect to make multiple revisions.

Summary

This chapter was a reflection on my experiences while developing the student-student discourse centered curriculum. My motivations stemmed from my personal experiences in a traditional classroom. Math is a core class and fundamental to everyday life but it is also a class that is losing many students because they feel that it isn't relevant to them. The literature I reviewed guided a large portion of how the curriculum was designed and was explained in the literature review section of this chapter. Limitations and plans to implement the curriculum were also discussed. By reflecting on my experiences during the development of the curriculum, I learned more about the answer to the capstone question: *How can teachers increase student-student discourse in math classrooms?*

Conclusion

There is an increasing need for classes to become more relevant by also teaching social-emotional skills (Jennings & Greenberg, 2009). Math classes can accomplish this through increasing student-student discourse but this can be challenging because of the lack of these opportunities in a traditional math classroom. Teachers can develop new curriculums that stray away from a standard mathematics curriculum. Doing so can introduce new learning experiences for students and positively impact students' perspectives of math.

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Appendix A
Minnesota K-12 Academic Standards in Mathematics

Grade	Strand	Standard	Code	Benchmark
9-11	Algebra	Understand the concept of function, and identify important features of functions and other relations using symbolic and graphical methods where appropriate.	9.2.1.4	Obtain information and draw conclusions from graphs of functions and other relations. ***For example:*** If a graph shows the relationship between the elapsed flight time of a golf ball at a given moment and its height at that same moment, identify the time interval during which the ball is at least 100 feet above the ground.
9-11	Algebra	Understand the concept of function, and identify important features of functions and other relations using symbolic and graphical methods where appropriate.	9.2.1.5	Identify the vertex, line of symmetry and intercepts of the parabola corresponding to a quadratic function, using symbolic and graphical methods, when the function is expressed in the form $f(x) = ax^2 + bx + c$, in the form $f(x) = a(x - h)^2 + k$, or in factored form.
9-11	Algebra	Understand the concept of function, and identify important features of functions and other relations using symbolic and graphical methods where appropriate.	9.2.1.6	Identify intercepts, zeros, maxima, minima and intervals of increase and decrease from the graph of a function.
9-11	Algebra	Understand the concept of function, and identify important features of functions and other relations using symbolic and graphical methods where appropriate.	9.2.1.7	Understand the concept of an asymptote and identify asymptotes for exponential functions and reciprocals of linear functions, using symbolic and graphical methods.
9-11	Algebra	Understand the concept of function, and identify important features of functions and other relations using symbolic and graphical methods where appropriate.	9.2.1.8	Make qualitative statements about the rate of change of a function, based on its graph or table of values. ***For example:*** The function $f(x) = 3^x$ increases for all x, but it increases faster when $x > 2$ than it does when $x < 2$.
9-11	Algebra	Understand the concept of function, and identify important features of functions and other relations using symbolic and graphical methods where appropriate.	9.2.1.9	Determine how translations affect the symbolic and graphical forms of a function. Know how to use graphing technology to examine translations. ***For example:*** Determine how the graph of $f(x) = \|x - h\| + k$ changes as h and k change.

Appendix B

Unit Summary

Students will expand their knowledge and understanding of quadratics. Students will also apply their new found knowledge to real life applications of quadratics.

MN Standards Met
• 9.2.1.5 - Identify the vertex, line of symmetry and intercepts of the parabola corresponding to a quadratic function, using symbolic and graphical methods, when the function is expressed in the form $f(x) = ax^2 + bx + c$, in the form $f(x) = a(x - h)^2 + k$, or in factored form. • 9.2.1.6 - Identify intercepts, zeros, maxima, minima and intervals of increase and decrease from the graph of a function.

Link to the Daily Plans Link to Student Packet Link to PowerPoint

Curriculum Information	**Helpful Resources**

<table>
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Class time: 50 minutes

<u>**Helpful Prerequisite Knowledge**</u>

- Exponents
- Solving for ‘x’ with the following operations: +,-, x, and ÷
- Graphing linear lines

<u>**Vocabulary**</u>

- Vertex
- Minimum
- Maximum
- Intersect
- Factor
- Equivalent
- Y-axis
- X-axis
- Increasing
- Decreasing
- Foil
- Distribute

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- Desmos Graphing Calculator
- Desmos Scientific Calculator

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Appendix C

Teacher Instructions

Day 1: Introduction to Quadratics

Lesson Length: 45 Minutes

Goal: Student can draw a parabola on a coordinate plane.
Student can state an example of parabolic motion in real life.
Student can determine whether an equation is or is not a quadratic.

Prepare before class

- Student Group Numbers/seating arrangements
- Hand students packet as they enter or have instructions to have them pick up a packet
- Presentation
- Quadratics

Introduction (5-10 min)

As students enter the room, hand them the quadratics packet and have the presentation showing entrance instructions

1. After students have time to draw their examples of the motion of an object that is thrown, have them move into their groups
2. Give them 3-5 minutes to compare and contrast their drawings and answer the questions in the packet
3. Come together as a group and discuss as a class what students noticed
4. Formally introduce Quadratics and move into the discussion

Notes:

Discussion (30-40 min)

1. Introduce the first question and immediately have students move into large groups to discuss and problem solve together.

2. After X minutes, come together as an entire class and share findings, wonderings, thoughts. **Be sure to highlight student findings that align with the goals stated above.**

3. Return to small groups and facilitate group discussions. Be sure to help groups that are stuck, lost, or having a difficult time starting
4. Regroup when you see that most groups are reaching the end of "Day 1"

Notes:

Closure (5-10 min)

1. Share findings and wonderings as a whole class

2. Have students individually fill out the survey as an exit ticket
   exit ticket may be a paper or google survey

Notes: *

Reflection (for teacher only)

Are there any changes needed for student groups?

Are there any parts of today's discussion that need to be further discussed?

Day 2: The Quadratic Equation

Lesson Length: 45 Minutes

Goal: Student can calculate if an equation is quadratic through calculating the 2nd differences from its table values.

Prepare before class

- Presentation
- Laptops
- Calculators

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) For the warm up, give students 5 minutes to work on it independently then 5 minutes to work on it with their group mates

2.) After group time, gather back as a whole class and have students share their equations being sure to have them NOT share if it IS or IS NOT. As a class discuss on whether an equation is or is not

3.) Do this activity as time permits.

4.) Move into the discovery

Notes:

Discovery (30-40 min)

1.) Have students begin the discovery activity after warm up

2.) As groups begin, be sure to walk around and facilitate learning. Make sure all groups have access to a graphing calculator or desmos.
   - a.) Be sure to note participation of students between groups on the student participation spreadsheet.

3.) After 10 minutes, gauge where groups are. If they are ready to regroup as a class, regroup and discuss findings. If not, give 5 more minutes and help groups finish up.

4.) At this point, emphasize to students "second differences" and how they tell us a function is quadratic.
5.) Have students move into #2 for 10 minutes. Walk around and check for understanding. See if students are using the second differences and ask them how they could make sure their table is
6.) Send groups up to demonstrate their tables and note the different values but similar shapes when graphed using demos. *finish with 5-10 minutes left for closure*

Notes:

Closure (5-10 min)

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

How are the conversations between students going?

Are there any groups who are have troubles with

Day 3: Vertex Form

Lesson Length: 45 Minutes

Goal: Student can write the equation of a quadratic in vertex form given its vertex.

Prepare before class

- Presentation
- Calculators
- Laptops

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) As students are working, walk around and look at student work.

2.) After 5 minutes, group up and ask for input from students. There is no wrong answer here to emphasize student participation and multiple perspectives.

3.) Move into part 2 of the warm up with groups. Start timer for 5 minutes.

4.) After 5 minutes, regroup and discuss various ways students found the vertex and how they represented it. Don't be afraid to call on groups.

5.) Move into discovery after

Notes:

Discovery (30-40 min)

1.) Students will immediately transition into discovery. They will spend 10-15 minutes to find the coordinates of the vertex and try to use it to translate the base function of $y = x^2$ so it has the corresponding vertex value.
    a.) Be sure to note participation of students between groups on the student participation spreadsheet.

2.) Regroup and share findings, having students explain their thought processes. MAKE SURE MULTIPLE GROUPS EXPLAIN THEIR PROCESS, even if it is the same, these opportunities are important.

3.) Move on to number 2 of discovery and continue facilitating learning between groups. (10 Minutes)

4.) Regroup and discuss findings. Have multiple groups show their thinking as time permits.

Notes:

Closure (5-10 min)

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

Are there any groups who are behind?

Are there any groups who haven't been check in on yet?

Day 4: Vertex Form II

Lesson Length: 45 Minutes

Goal: Student can change a standard form quadratic equation into vertex form.

Prepare before class

- Presentation
- Calculators
- Laptops

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) As class starts, begin the 5 minute timer. Be sure to be walking around the room during this time and help students who are struggling.

2.) Regroup and discuss student thoughts and findings. Do not move on after just 1 answer. Look for 2-3 answers even if they are the same. Emphasize to students that hearing what multiple students did is very helpful

3.) Wait for questions, then move on to discussion.

Notes:

Discovery (30-40 min)

1.) Before discovery, show students the first slide with h=-b/2a. Tell them that this is how they can solve for the x coordinate without using a graph.

2.) Answer questions then move into solving part a.

3.) After 15 Minutes, regroup and discuss findings being sure to allow for multiple perspectives.

4.) Have students try number part b and start timer. During this time, walk around and help groups.

5.) Regroup and go over the solutions of different groups. Be sure to call on different groups. Emphasize that it is okay to not have a complete answer.

6.) Move into number 2. Facilitate learning within groups too during this time.

7.) Be mindful of the time and end early if needed so students have time for closure.

8.) Regroup and talk about what students tried, not the solutions specifically.

Notes:

Closure (5-10 min)

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

How is facilitating lessons going? Are there groups you are focusing TOO much on?

Day 5: Factored Form

Lesson Length: 45 Minutes

Goal: Student can write the equation of a quadratic in Factored form given its roots.

Prepare before class

- Presentation
- Calculators
- Laptops

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) As students are attempting the warm-up, walk around and help students who have blank responses. Emphasize that there is no right or wrong answer here.
2.) When the timer is up, as a class, discuss the various importances of 'zero'. Write them all down on the board
3.) Answer questions and wonders them move into discovery.

Notes:

Discovery (30-40 min)

1.) Have students work in groups immediately. This activity can be challenging as students will have to pull on past knowledge to create an example of factoring.

2.) If students are having a difficult time, try asking them to work backwards and foil to create an example of how to factor.

3.) After 10 minutes, regroup and discuss findings from all groups.

4.) Return to groups and have students talk about number 2 of discovery. Walk around during this time and assist groups in this discussion. (5-10 min depending on class needs)

5.) Regroup and discuss findings and the importance of factoring. Answer questions and wonderings.

6.) Move into number 3 of discovery. Once groups finish, select a few groups to present their solution and how they got it. This can take time so choose as many groups as time permits.

Notes:

Closure **(5-10 min)**

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

How are the conversations between students going?

Are there any groups who are have troubles with

Day 6: Factored Form II

Lesson Length: 45 Minutes

Goal: Student can find the roots of a form quadratic equation into factored form using the quadratic formula.

Prepare before class

- Calculators
- Presentation

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) This warm up relies on knowledge from the previous day and can be challenging. Emphasize to the class that it is okay to NOT have a complete answer with facting the equations.

2.) Once the timer goes off, have students/groups go over their thought processes and solutions.

3.) Have students discuss number 2 on the warm up for 5 minutes then regroup to share thoughts.

4.) Answer questions and move into discovery.

Notes:

Discovery (30-40 min)

1.) Before moving into the discovery, introduce the quadratic formula to students. Answer questions and emphasize to students that we will be discovering how to use the formula in today's activity.

2.) Move into discovery number 1. During this time, facilitate learning in groups, giving time for groups to struggle and discuss strategies.

3.) After 10 minutes, regroup as a whole class and discuss findings. Highlight how groups know what stands for variable a, b, and c in the quadratic formula.
4.) Move into number 2 of discovery. During this time, check on groups and help groups that are stuck. Make sure groups are including all members into the conversation.
5.) After 10 minutes, regroup and discuss findings as a whole class and move onto closure of lesson.

Notes:

Closure **(5-10 min)**

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

How are the conversations between students going?

Are there any groups who are have troubles with

Day 7: Graphing Quadratics

Lesson Length: 45 Minutes

Goal: Student can graph a quadratic equation using the roots or vertex.

Prepare before class

- Student Group Numbers
-
- Presentation
- Quadratics

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) During warm up, walk around and help students with graphing. Don't explicitly state how to do it, rather listen to their ideas. Encourage students to ask their group mates for help during this time.

2.) Regroup as a class after the timer goes off. Have multiple students/groups explain their thought process while graphing the function.

3.) Ask for wonderings before moving onto discovery.

Notes:

Discovery (30-40 min)

1.) Immediately have students begin on discovery number 1. This one is very challenging and chances are many groups will struggle to get a start on this confidently. Facilitate closely and help groups find a strategy. There are many ways to complete this task so make sure groups are using multiple perspectives.

2.) After 15 minutes, regroup as a whole class and go over strategies. If groups need more time, return to group work and facilitate small groups.

3.) After groups complete number 1, move on to number 2. Work on this for 10 minutes and facilitate groups.

4.) Regroup and discuss what groups did to solve this. Emphasize what is different about the shape of the graph. *emphasize on how previous graphs were up like a cup and this one is down like a frown.

5.) Inquire the whole class why they think that is so.

6.) Wrap up the lesson and move into closure.

Notes:

Closure **(5-10 min)**

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

How are the conversations between students going?

Are there any groups who are have troubles with

Day 8: Graphing Quadratics II

Lesson Length: 45 Minutes

Goal: Student can solve for the stretch/shrink factor of a quadratic using the y-intercept.

Prepare before class

- Student Group Numbers
- Hand students
- Presentation
- Quadratics

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) Walk around the room and give groups pointers as to how to start this problem.

2.) After 5 minutes, give students a hint as a whole group and proceed on group work for another 5 minutes.

3.) Return as a whole group and ask multiple groups how they started solving for the equation.

4.) Show a solution and one possible method, emphasizing how there are multiple approaches.

5.) Move into discovery after answering wonderings and questions

Notes:

Discovery (30-40 min)

1.) Students will move into the discovery right away. Facilitate groups during this time and be aware of groups who need clarification. There is a note at the bottom that further explains the task.

2.) After 10 minutes, regroup and discuss how students started this problem. Ask for multiple groups to put their input.

3.) Proceed to number 2 in groups and facilitate groups as they solve number 2.
4.) Regroup and discuss how to turn a factored form equation into standard form.

Notes:

Closure **(5-10 min)**

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

Are there students who need to be moved?

Is there a catch up day that is needed? Before application problems?

Day 9: Applying Quadratics

Lesson Length: 45 Minutes

Goal: Student can calculate the distance that a thrown ball travels using the roots.

I can calculate the maximum height of a ball that is thrown using the vertex.

Prepare before class

- Student Group Numbers
- Hand students
- Presentation
- Quadratics

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) As students start working on the warm up, make sure students at least have a start on number 1. Emphasize students who draw the parabola to add a coordinate grid.

2.) After 5 minutes, move into group work and have students work on the warm-up as in small groups for 5 minutes.

3.) Once most groups have an attempt, regroup as a whole class and discuss possible answers for each number. Emphasize explanations and thought processes.

4.) Finish warm-up and move into discovery.

Notes:

Discovery (30-40 min)

1.) Have small groups start on the discovery activity. During this time, facilitate groups and make sure groups have a strong start.

2.) After 15 minutes, regroup as a whole class and discuss approaches for #1-3

3.) After questions and discussion, move onto number 4. Regroup after 15 minutes.

4.) Inquire students about what the meaning of these values could mean. If time permits, discuss what -16 could be if it were to be in meters instead of ft.

Notes:

Closure (5-10 min)

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

Are ELL students understanding what is being asked from the application problems?

Day 10: Applying Quadratics

Lesson Length: 45 Minutes

Goal: Student can write the equation of a ball to determine the maximum height traveled.

Prepare before class

- Student Group Numbers
- Hand students
- Presentation
- Quadratics

Introduction (5-10 min)

Have the entrance instructions and warm-up presented on the board as students enter the room

1.) As students are trying out the warm-up. Walk around and have small discussions with groups to gauge where the class is at.
2.) After 5 minutes, have students turn and talk for 5 minutes then share as a whole class as time permits.
3.) Transition into discovery.

Notes:

Discovery (30-40 min)

1.) Students will continue expanding knowledge of applications using the same problem as day 9. This time students write the equation of the kick. Make sure to note that they CAN use information from yesterday to help.
    a.) Work with groups to help them get a start if they are stuck
2.) After 15 minutes, regroup as a class and discuss findings/strategies. Always ask for multiple groups to speak on what they have so far. There is no finish line here.
3.) Move onto problem 3 after discussing #1 and 2. This problem may take more time as there is less readily available infor
    a.) Question students about what ‘a’ could be considering that it is not explicitly stated.
4.) After 15 minutes, regroup and discuss strategies.
5.) Move onto closure after.

Notes:

Closure (5-10 min)

1.) Share findings and wonderings as a whole class

2.) Have students individually fill out the survey as an exit ticket
exit ticket may be a paper or google survey

Notes:

Reflection (for teacher only)

What could you do MORE of?

What could you do LESS of?

Appendix D

Student Packet

Quadratics

Advanced Algebra

Mr. Vang

Room 200

Day 1: Introduction to Quadratics

Warm-up

1.) If you were to throw an object, what would its motion look like?

Sketch what you think it would look like here

2.) Answer the questions below with your group.

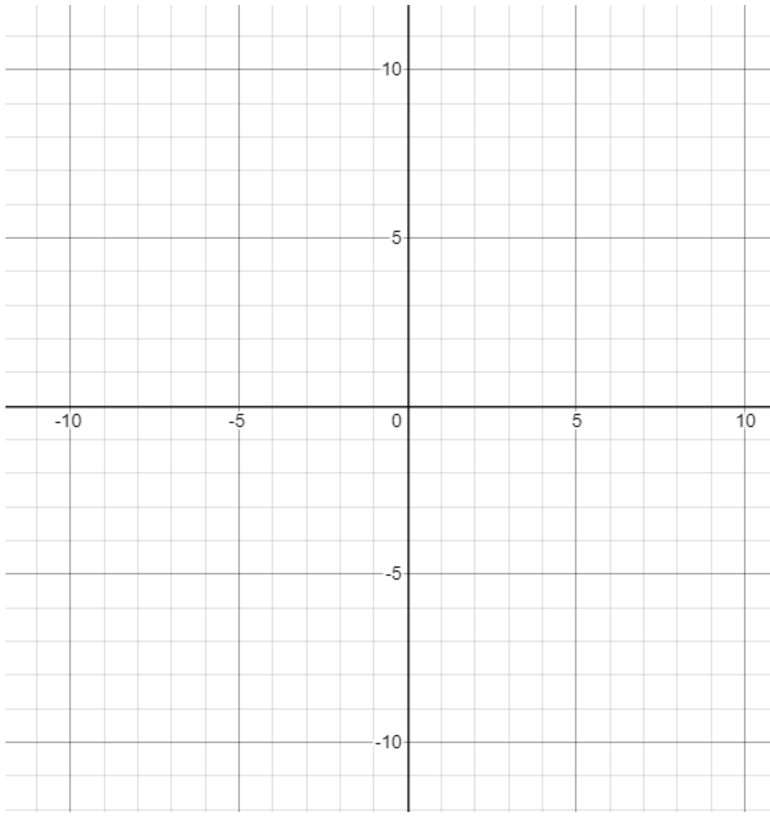
a.) How are your drawings similar?

b.) How are your drawings different?

Discovery

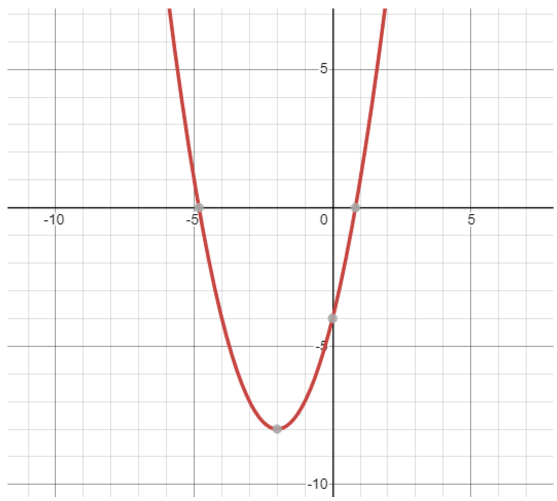
1.) Try sketching a parabola on the graph below.

Key Features

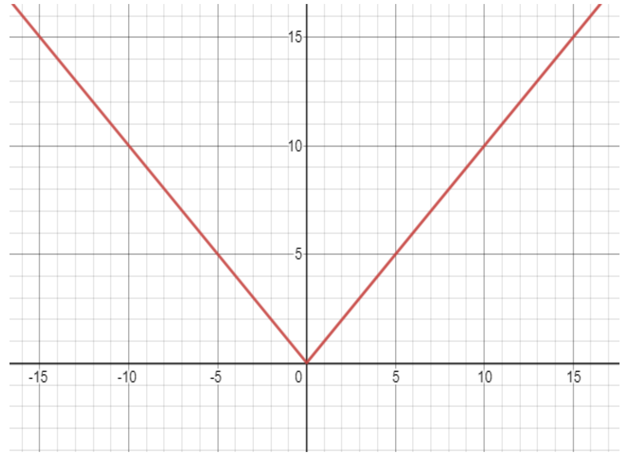


2.) With your group, determine whether the following graphs are examples of a quadratic function or not.

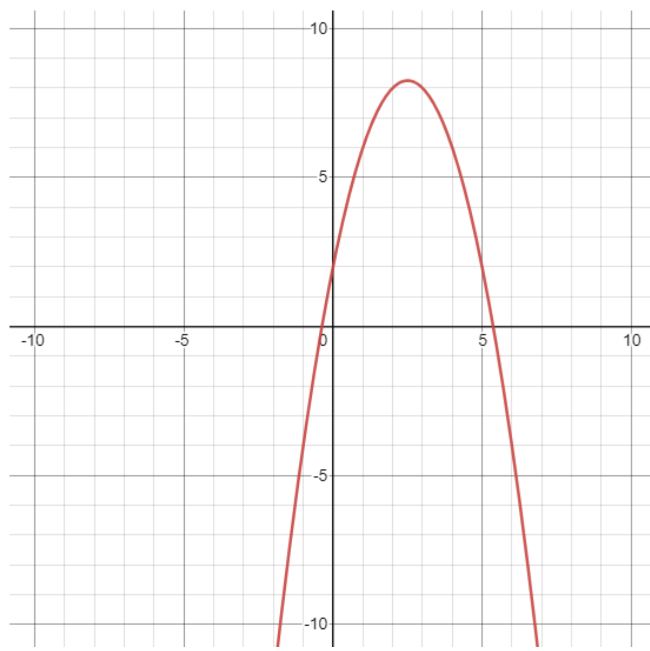
a.) Is this a quadratic function? Explain why or why not.



b.) Is this a quadratic function?
Explain why or why not.



c.) Is this a quadratic function?
Explain why or why not.



3.) With your group, determine why or why not the following equations are quadratics.

a.) $y = x^2 + 5$

b.) $y = 9x + 1$

c.) $y = x^2 + 2x^3 - 5$

d.) $y = 6x^2 + 4x - 3$

4.) Create your own equation and see if your group can determine if it is a quadratic equation or not.

Closing

Exit Ticket

1.) Answer the following statements on a scale of 1 to 5, 1 being not confident at all and 5 being very confident.

a.) I can draw a parabola on a coordinate plane. _____

b.) I can state an example of parabolic motion in real life. _____

c.) I can identify quadratic equations from a list of various equations. ____

2.) What is your least favorite chore?

Day 2: The Quadratic Equation

Warm-up

1.) Create an equation that IS NOT a quadratic and one that IS a quadratic.

IS NOT:

IS:

Discovery

1.) Using a graphing calculator, or desmos, graph the following quadratic equation:

$$y = x^2 + 5$$

a.) With your group, fill out the table for the equation.

x	y
0	
1	
2	
3	
4	

b.) With your group, discuss what you notice about the rate of increase/decrease?

c.) With your group, determine if the table below represents a quadratic.

x	y
0	2
1	4
2	6
3	8
4	10

Discuss and write down why you think **it is** or **is not** a quadratic.

2.) Create a table that DOES represent a quadratic.

x	y

Closing

What is something you learned today?

What is something you still have wonderings about?

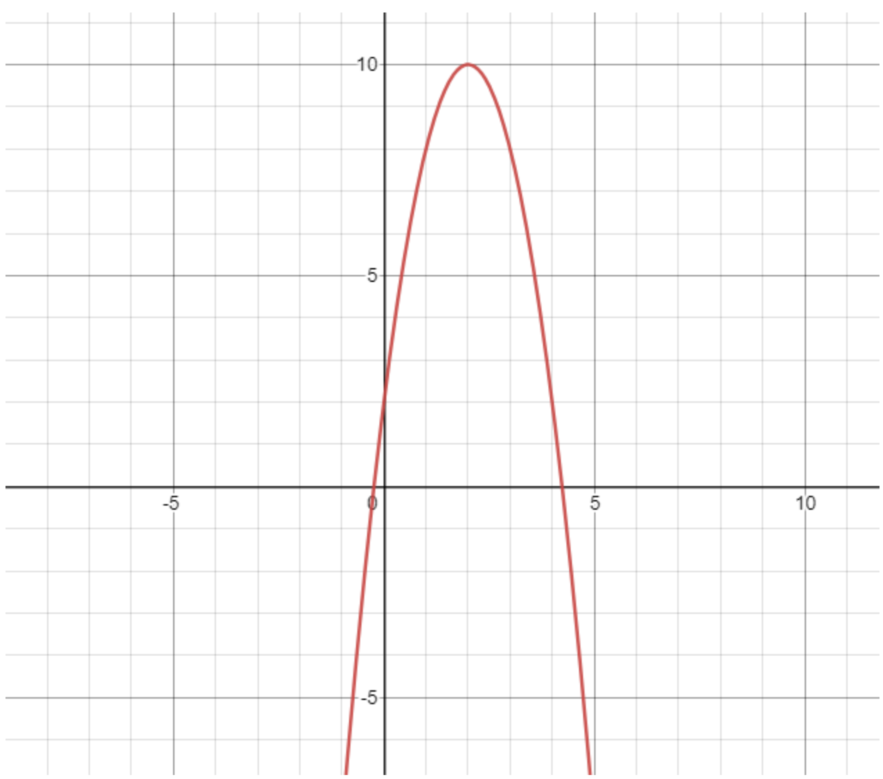
Day 3: Vertex Form

Warm-up

1.) What comes to mind when you hear the word VERTEX?

Only work on #1 for the first part of this warm-up

2.) With your group find the vertex for the following quadratic.



Discovery

1.) Using desmos, Graph the following quadratic:

$$y = x^2 + 8x + 14$$

a.) What are the coordinates of its vertex?

b.) The base function of a quadratic is $y = x^2$. Using what you know about translations, try writing the quadratic above in Vertex form.

2.) Can quadratics share the same vertex? Show why or why not.

Closing

1.) Why do you think someone would want to use vertex form?

2.) How do you feel about the pacing of lessons? Are things going too slow or too fast?

Day 4: Vertex Form II

Warm-up

1.) For the equation below, if you know that the **vertex** has an x-coordinate of x=5, how could you find its corresponding y-coordinate?

$$y = x^2 + 6x + 4$$

Discovery

1.) Using $h = \frac{-b}{2a}$.

a.) The equation for a ball that was thrown is:

$$y = -x^2 + 8x + 14.$$

Assuming that y=0 is the ground, how high did the ball go?

b.) Using the vertex you found, what is the equation for the ball in vertex form?

2.) *Going backwards*. Discuss and try with your group to turn this quadratic equation in vertex form, back into standard form.

$$y = (x + 5)^2 + 3$$

Closing

1.) Answer the following statements on a scale of 1 to 5, 1 being not confident at all and 5 being very confident.

a.) I can locate the vertex of a quadratic on a coordinate plane.

____

b.) I can calculate the vertex of a quadratic using $h = \frac{-b}{2a}$.

____

2.) *Replace with any fun question* Ex. " Why is your favorite fruit your favorite fruit?"

Day 5: Factored Form

Warm-up

Come up with as many reasons as you can why the number zero is important.

Discovery

1.) What does it mean to factor something? Show an example

2.) What does factoring tell us about?

3.) When does the following quadratic equation equal zero?

$$y = x^2 + 2x - 3$$

Closing

1.) Why do you think factored form is useful?

2.) How do you feel about the lesson pacing and structure?

3.) *Replace with a fun question* ex. “If you could eat only one thing for a whole year, what would it be?”

Day 6: Factored Form II

Warm-up

1.) Factor the following equations:

$$y = x^2 - 2x + 12$$

$$y = x^2 - 5x - 9$$

2.) What do you notice about solving the first one compared to the second one?

Discovery

1.) Using the quadratic formula, find the roots of the following quadratic:

$$y = 2x^2 + 3x - 11$$

2.) With the roots you found, write the equation in factored form.

Closing

What is a strength of using factoring?

What is a weakness of using factoring?

What is a strength of using the quadratic formula?

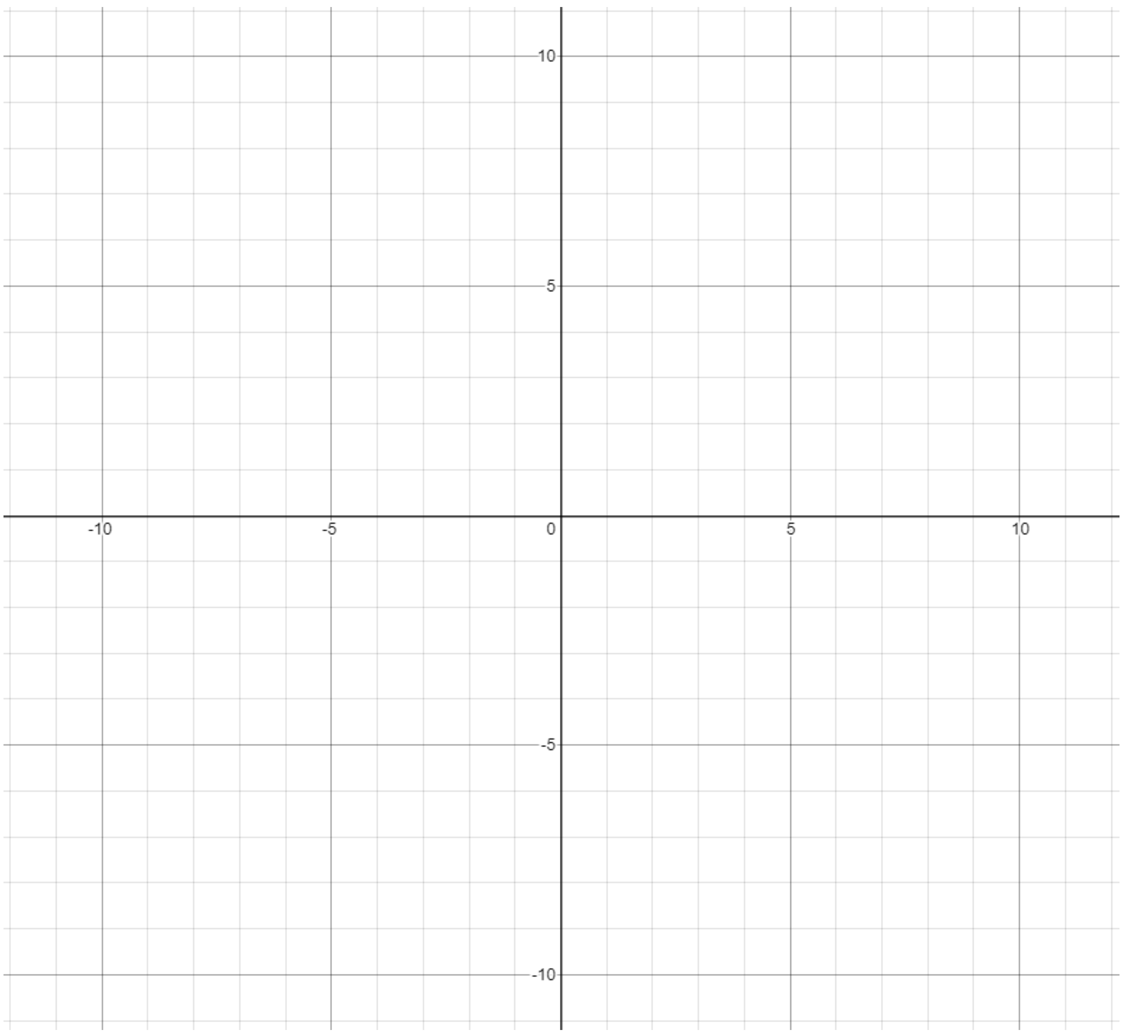
What is a weakness of using the quadratic formula?

Day 7: Graphing Quadratics

Warm-up

Graph the following linear equation:

$$y = 2x + 5$$

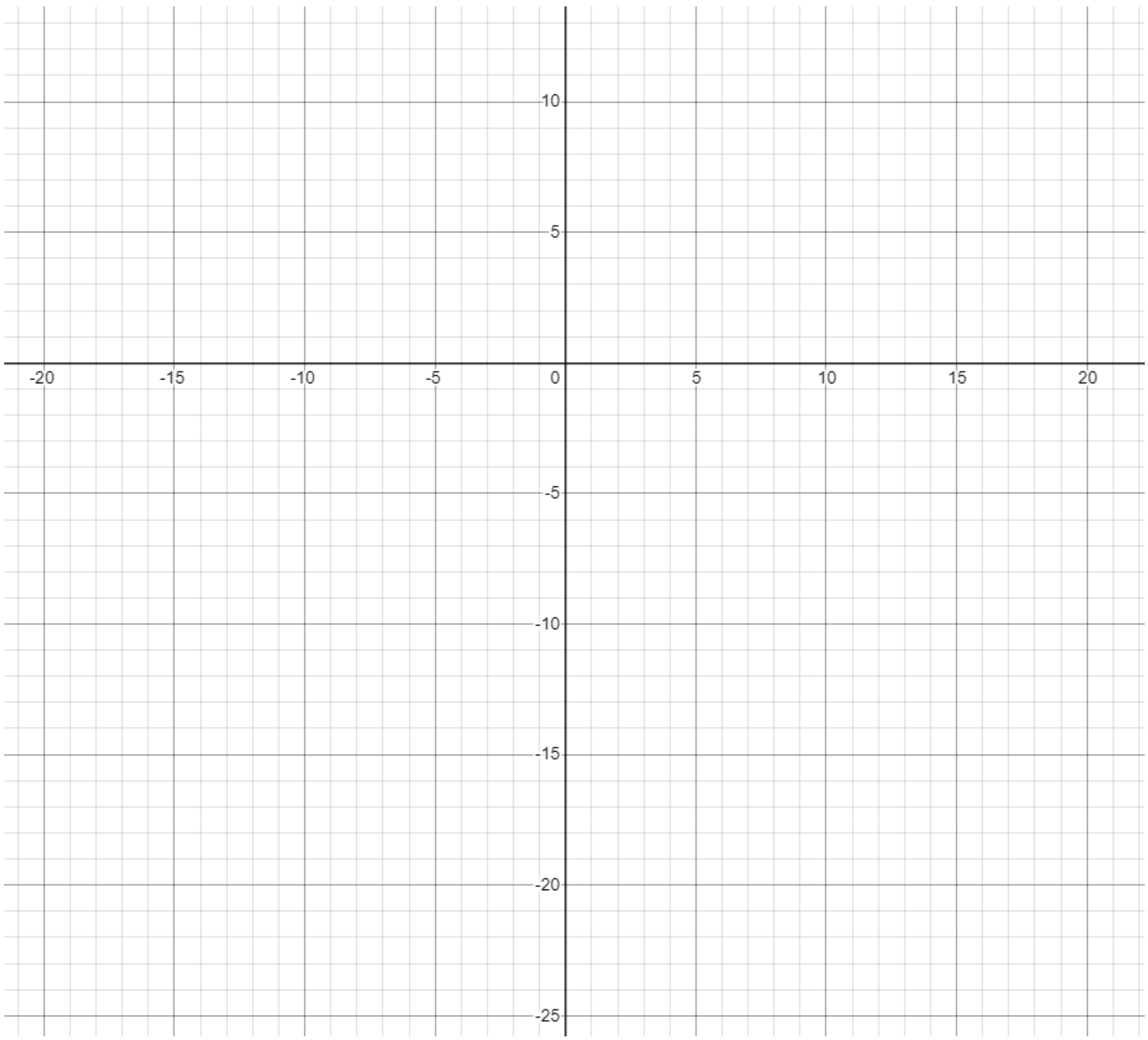


Describe how you graphed it.

Discovery

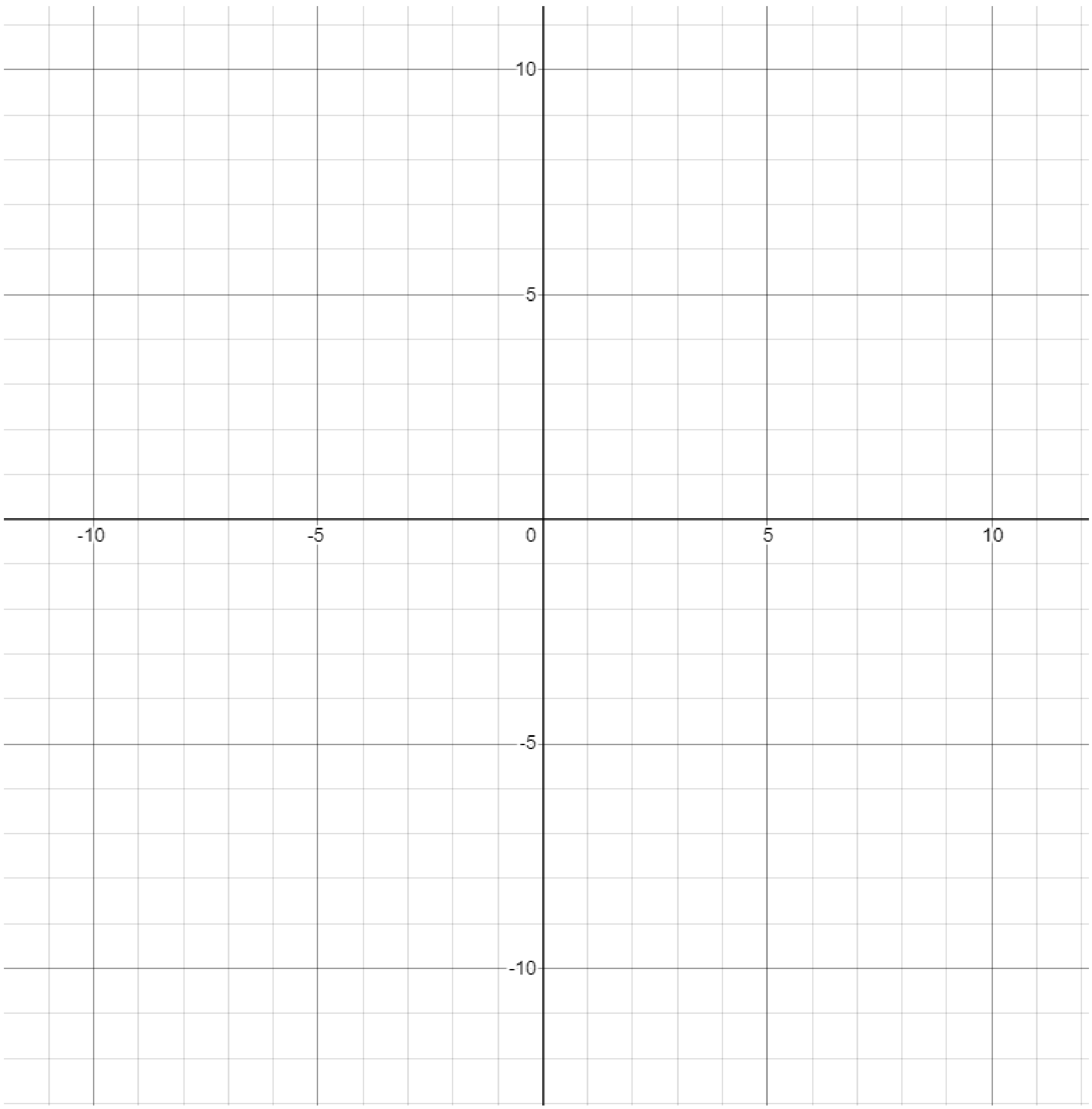
1.) With your group, devise a way to graph the following function:

$$y = 2x^2 - 10x - 12$$



2.) Now try graphing the following function

$$y = -x^2 - 5x - 9$$



Closing

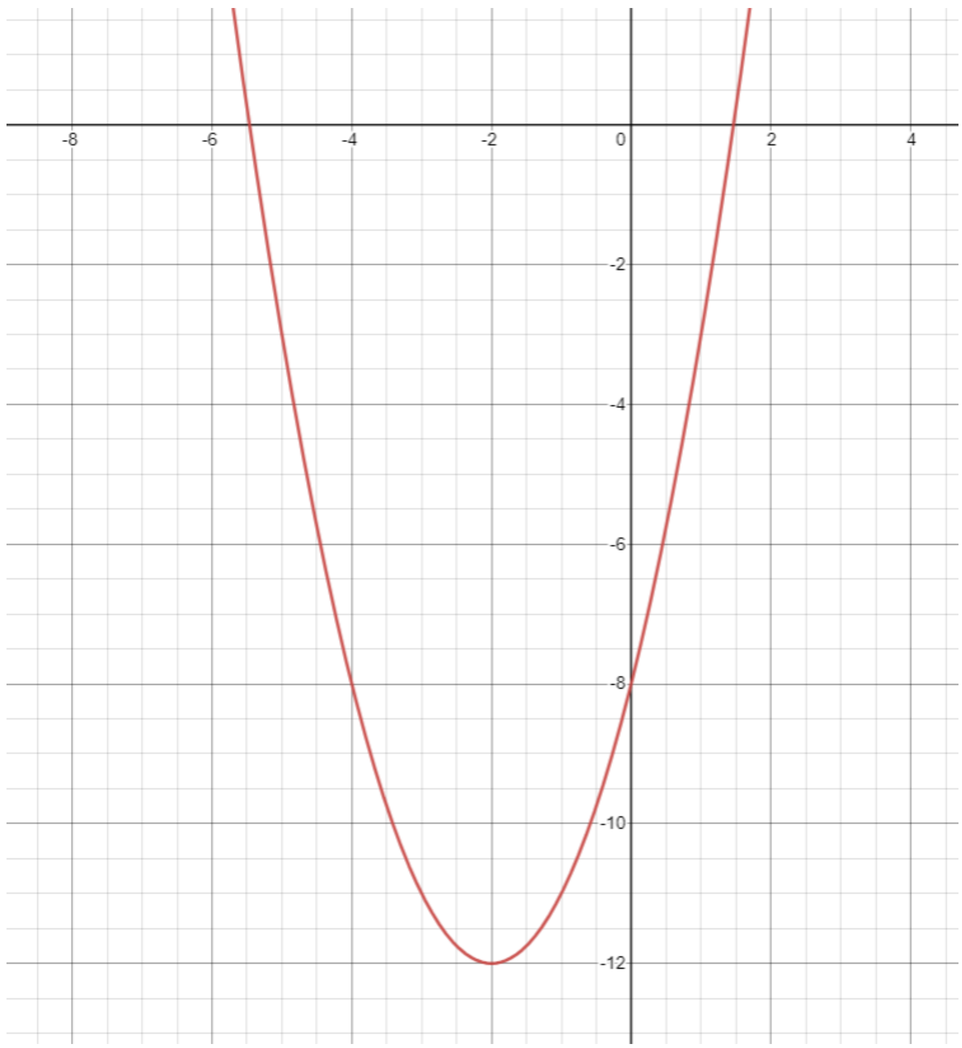
1.) Are there any parts of quadratics that you wish we had more time on?

2.) *Replace this text with a fun question* Ex. “ If you could be any animal for one day, what animal would you be and why?”

Day 8: Graphing Quadratics II

Warm-up

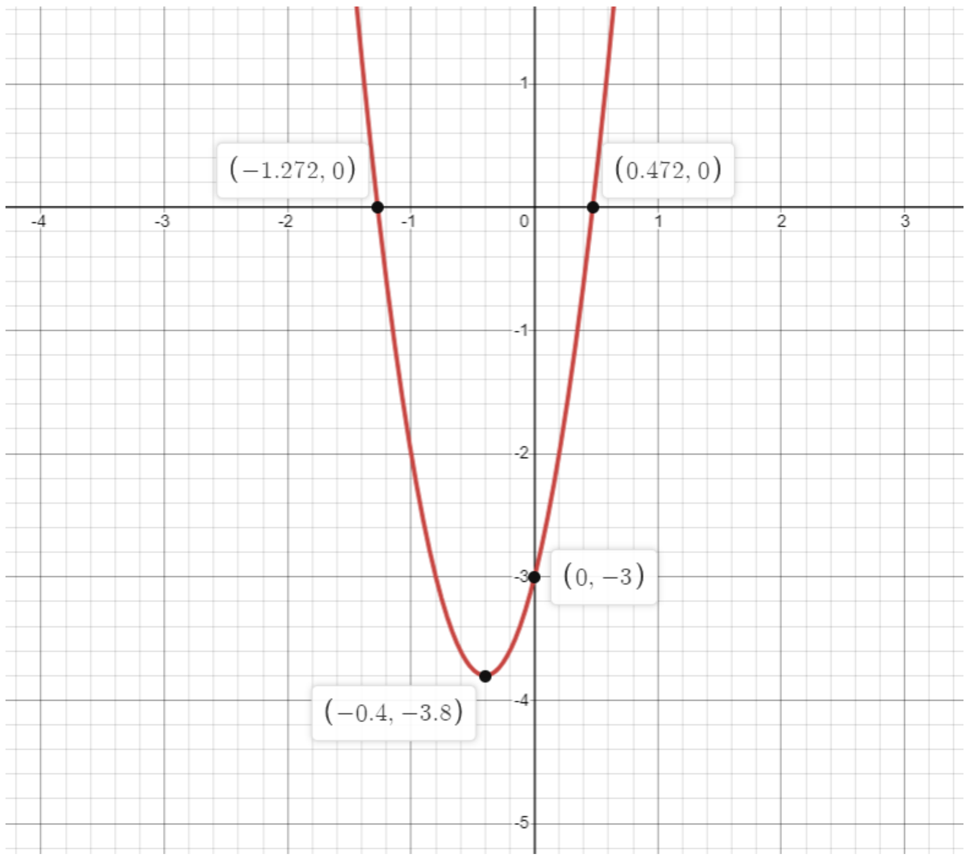
1.) Give your best shot at writing the equation for the following graph.



2.) With your group, compare and contrast the steps you took and write down what you noticed.

Discovery

1.) Alex wrote a quadratic equation for the following graph in factored form.



He got $y = (x - .472)(x + 1.272)$.When he graphed it it didn't quite match up with the graph he was given. With your group, figure out where he went wrong.

2.) With your group, convert Alex's fixed equation into standard form.

Closing

1.) What do you think needs to be considered when writing the equation for a quadratic?

2.) How do you feel about the time given to work with groups? Do you want to see more time? Less time?

Day 9: Applying Quadratics

Warm-up

1.) Draw the motion of a ball that is thrown on a graph

2.) What represents the starting point of the ball and what represents the ending point of the ball?

3.) How about the highest point of the ball?

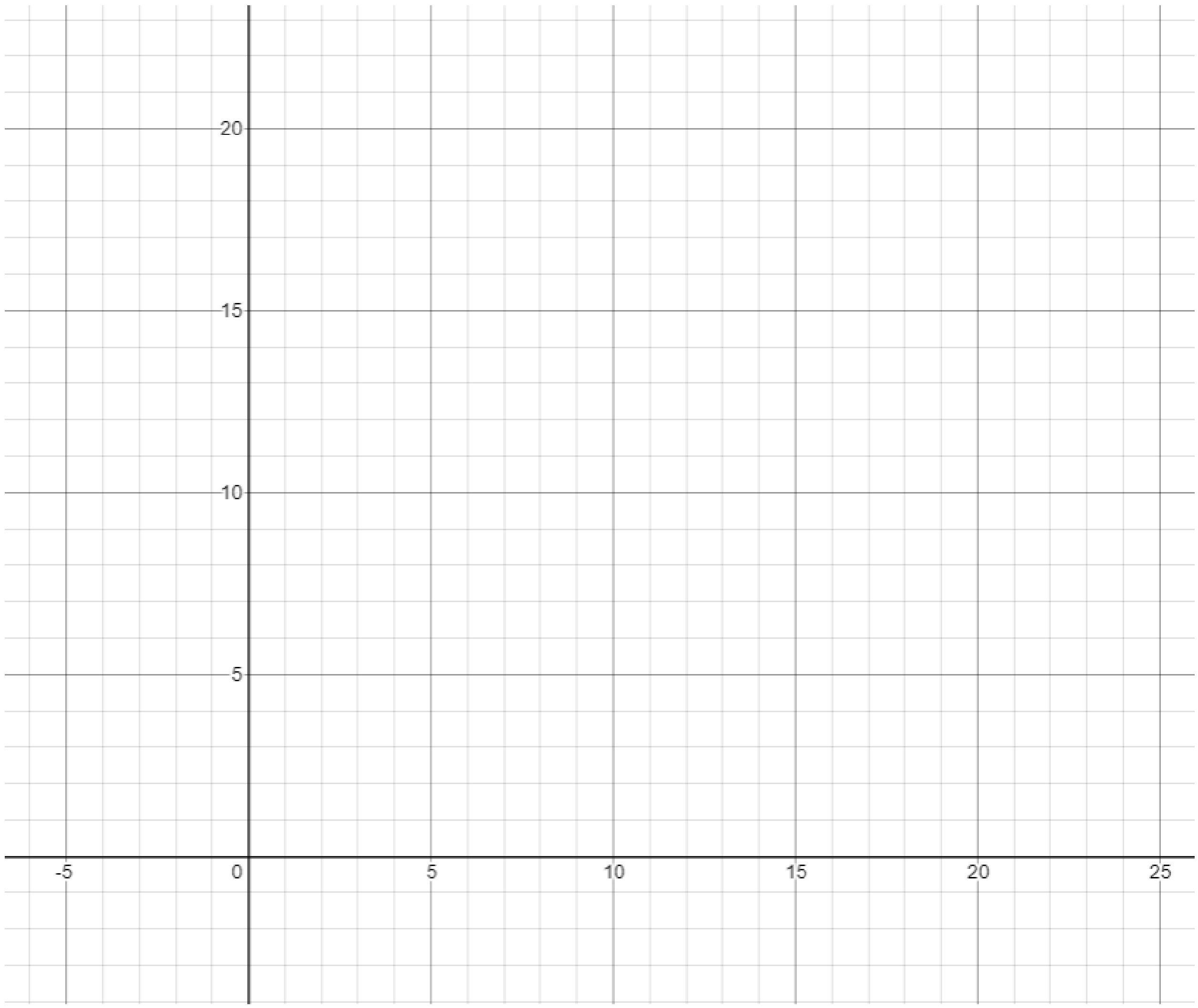
Discovery

(With your group)
Kerry is kicking a ball in the air as high as she can. Her best kick is represented by the function $h(t) = -16t^2 + 35t + 1$.

1.) What does the variable h stand for?

2.) What does the variable t stand for?

3.) Plot the ball on a coordinate grid.



4.) Guessing time:

a.) What could -16 mean? Why do you think so?

b.) What could +35 mean? Why do you think so?

c.) What could +1 mean? Why do you think so?

Closing

1.) How do you feel about guessing in mathematics?

Day 10: Applying Quadratics II

Warm-up

Why should we guess?

How do you feel when you guess?

Discovery

Kerry is kicking a ball in the air as high as she can. Her best kick is represented by the function $h(t) = -16t^2 + 35t + 1$.

1.) How high does she kick the ball?

2.) How far does the ball go?

3.) Kerry tries to beat her current record. She kicks the ball at 34 feet per second and 2 feet off the ground.

a.) Write the equation that represents this kick.

b.) Does this kick beat her current record?

Closing

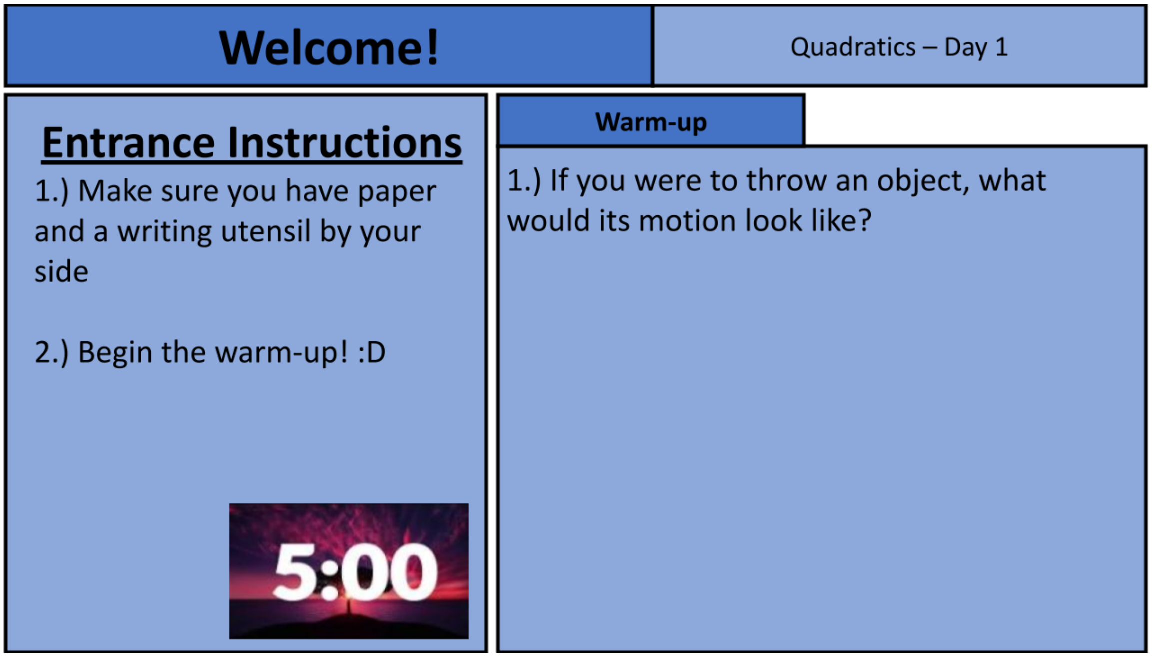
1.) How do you feel about this format of learning?

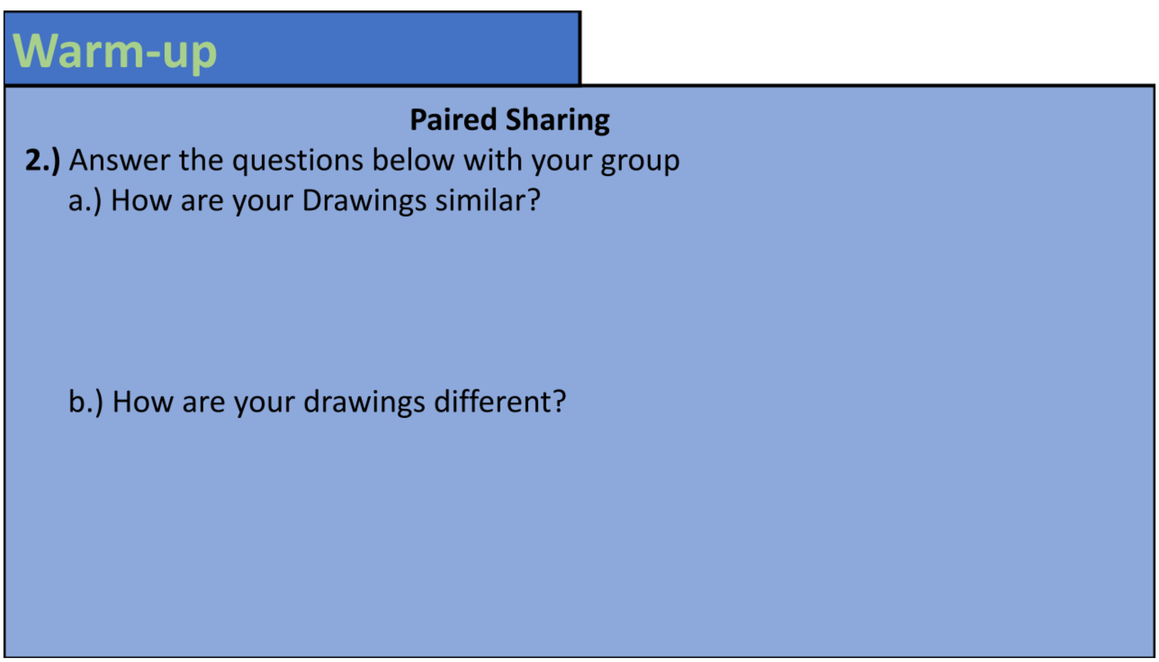
2.) What are 2 things you enjoyed about this format of learning?

3.) What are 2 things you did not enjoy about this format of learning?

Appendix E

Powerpoint Slides

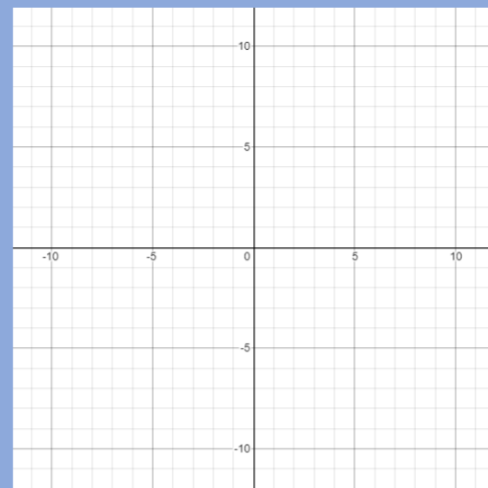




Discovery

1.) Try sketching a parabola on the graph below.

Key Features

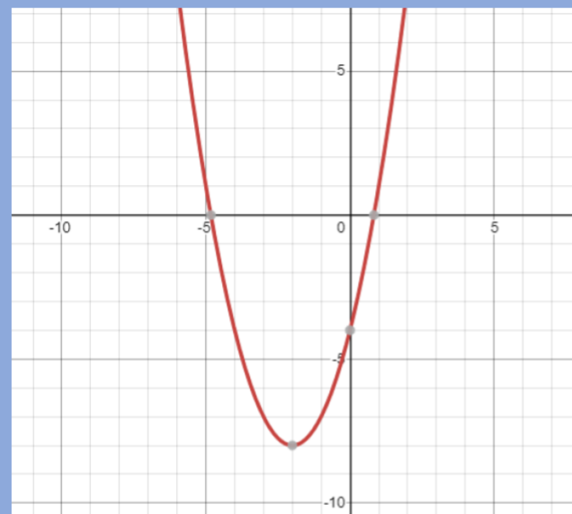


Discovery

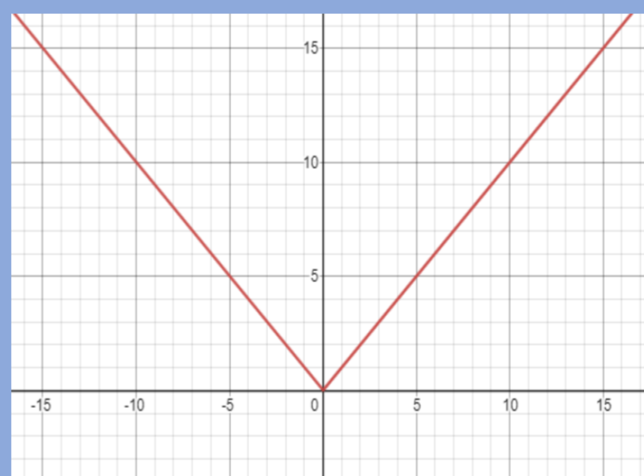
2.) With your group, determine whether the following graphs are examples of a quadratic function or not.

Gather back in 10 Minutes

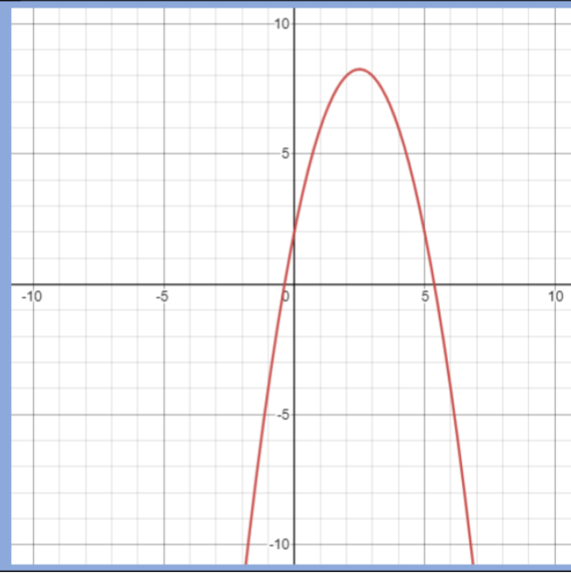
a.)Is this a quadratic function?
Explain why or why not.



a.)Is this a quadratic function?
Explain why or why not.



a.)Is this a quadratic function?
Explain why or why not.



Discovery

3.) With your group, determine why or why not the following equations are quadratics.

Gather back in 10 Minutes

Discovery

a.) $y = x^2 + 5$

b.) $y = 9x + 1$

Discovery

c.) $y = x^2 + 2x^3 - 5$

d.) $y = 6x^{2} + 4x - 3$

Discovery

4.) Create your own equation and see if your group can determine if it is a quadratic equation or not.

Discovery

Extra work space

Closing

Questions and comments

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period’s “exit ticket” bin.

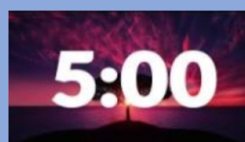
Welcome!

Quadratics – Day 2

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



Warm-up

1.Create an equation that IS NOT a quadratic and one that IS a quadratic.

IS NOT:

IS:

Warm-up

1.Create an equation that IS NOT a quadratic and one that IS a quadratic.

IS NOT:

IS:

Discovery

With your group, work through #1 of Discovery

Discovery

1.) Using a graphing calculator, or desmos, graph the following quadratic equation:

$$y = x^2 + 5$$

a.) With your group, fill out the table for the equation

x	y
0	
1	
2	
3	
4	

Discovery

b.) With your group, discuss what you notice about the rate of increase/decrease?

$y = x^2 + 5$

x	y
0	5
1	6
2	9
3	14
4	21

Discovery

c.) With your group, determine if the table below represents a quadratic.

x	y
0	2
1	4
2	6
3	8
4	10

Discuss and write down why you think **it is** or **is not** a quadratic.

Discovery

2.) Create a table that DOES represent a quadratic.

x	y

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

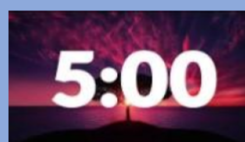
Welcome!

Quadratics – Day 3

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



Warm-up

Only work on number 1

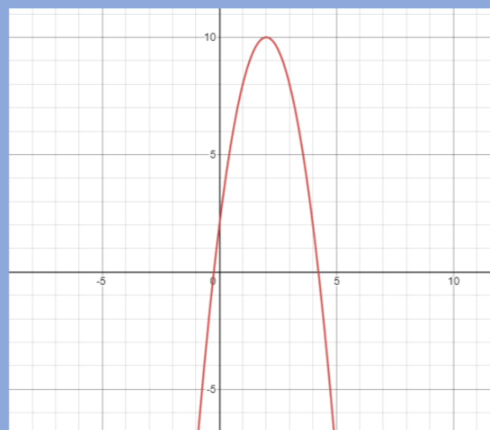
1. What comes to mind when you hear the word VERTEX?

Warm-up

1.) What comes to mind when you hear the word VERTEX?

Warm-up

2.) With your group find the vertex for the following quadratic.



Discovery

1.) Using desmos, Graph the following quadratic:

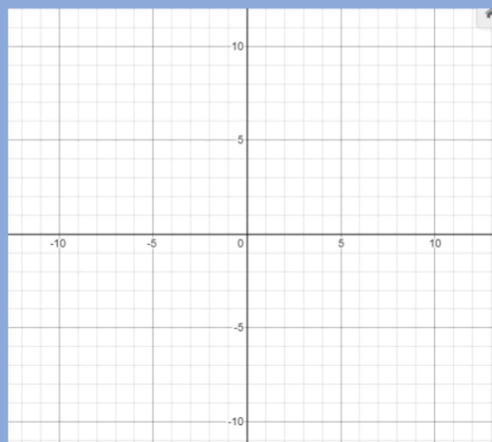
$$y = x^2 + 8x + 14$$

a.) What are the coordinates of its vertex?

b.) The base function of a quadratic is $\boldsymbol{y = x^2}$. Using what you know about translations, try writing the quadratic above in Vertex form.

Discovery

2.) Can quadratics share the same vertex? Show why or why not.



Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

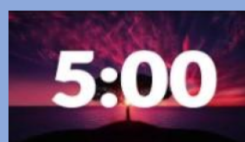
Welcome!

Quadratics – Day 4

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



Warm-up

1.) For the equation below, if you know that the **vertex** has an x-coordinate of x=5, how could you find its corresponding y-coordinate?

$$y = x^2 + 6x + 4$$

Warm-up

1.) For the equation below, if you know that the **vertex** has an x-coordinate of x=5, how could you find its corresponding y-coordinate?

$$y = x^2 + 6x + 4$$

Discovery

1.) Using $h = \frac{-b}{2a}$.

a.) The equation for a ball that was thrown is:

$$y = -x^2 + 8x + 14$$

Assuming that the ball was thrown from the ground, how high did the ball go?

Discovery

b.) Using the vertex you found, what is the equation for the ball in vertex form?

Discovery

3.) *Going backwards*. Discuss and try with your group to turn this quadratic equation in vertex form, back into standard form.

$$y = (x + 5)^2 + 3$$

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

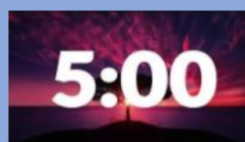
Welcome!

Quadratics – Day 5

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



Warm-up

1.) Why is 'zero' so important?

Warm-up

1.) Why is 'zero' so important?

Discovery

1.) What does it mean to factor something? Show an example

Discovery

2.) What does factoring tell us about?

Discovery

3.) When does the following quadratic equation equal zero?

$$y = x^2 + 2x - 3$$

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period’s “exit ticket” bin.

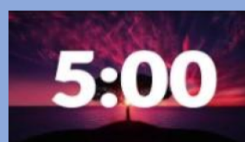
Welcome!

Quadratics – Day 6

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D

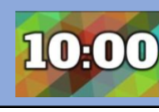


Warm-up

1.) Factor the following equations:

$$y = x^2 - 2x + 12$$

$$y = x^2 - 5x - 9$$



Warm-up

1.) Factor the following equations:

$$y = x^2 - 2x + 12$$

$$y = x^2 - 5x - 9$$

Warm-up

2.) What do you notice about solving the first one compared to the second one?

Discovery

We can also solve for the roots using the quadratic formula!

For: $y = ax^2 + bx + c$

Quadratic Formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

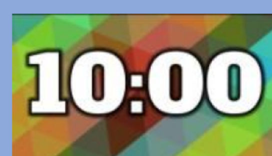
Discovery

1.) Using the quadratic formula, find the roots of the following quadratic:

$$y = 2x^2 + 3x - 11$$

Discovery

2.) With the roots you found, write the equation in factored form.



Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

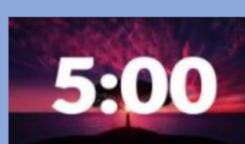
Welcome!

Quadratics – Day 7

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

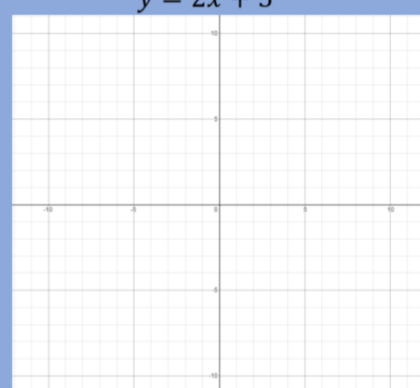
2.) Begin the warm-up! :D



Warm-up

1.) Graph the following linear equation and describe how you graphed it.

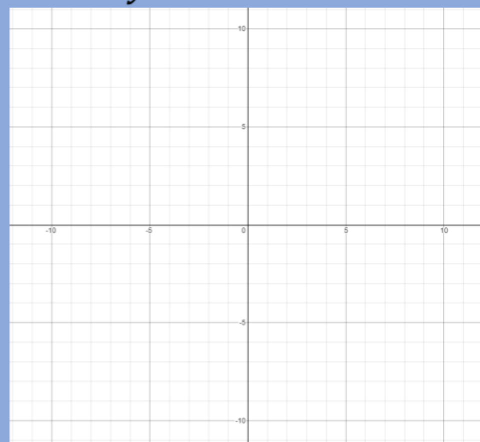
$$y = 2x + 5$$



Warm-up

1.) Graph the following linear equation and describe how you graphed it.

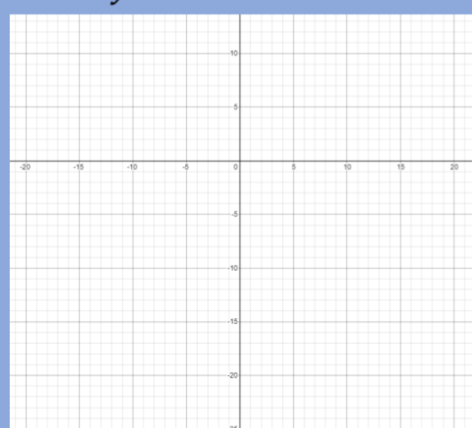
$$y = 2x + 5$$



Discovery

1.) With your group, devise a way to graph the following function:

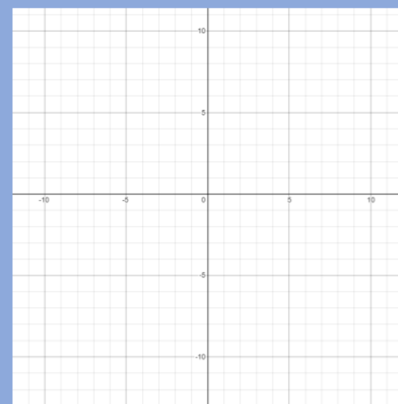
$$y = 2x^2 - 10x - 12$$



Discovery

2.) Now try graphing the following function:

$$y = -x^2 - 5x - 9$$



Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

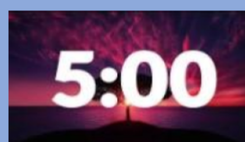
Welcome!

Quadratics – Day 8

Entrance Instructions

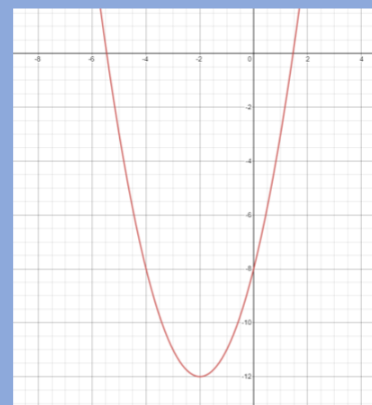
1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



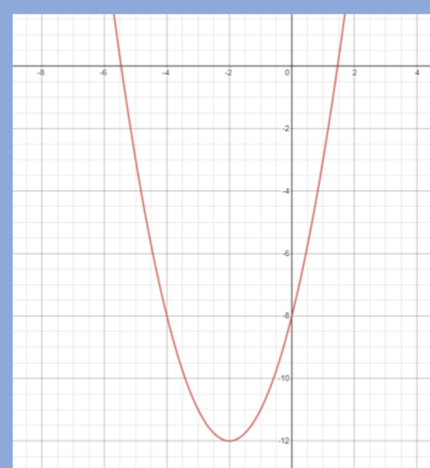
Warm-up

1.) Give your best shot at writing the equation for the following graph.



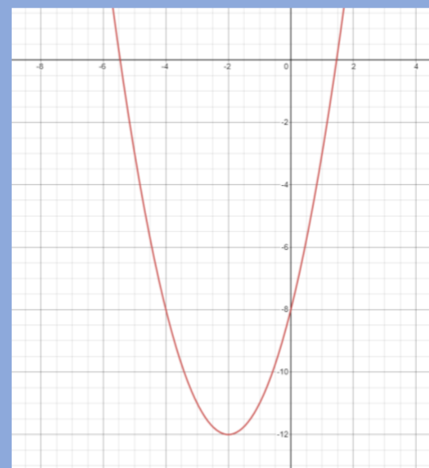
Warm-up

1.) Give your best shot at writing the equation for the following graph.



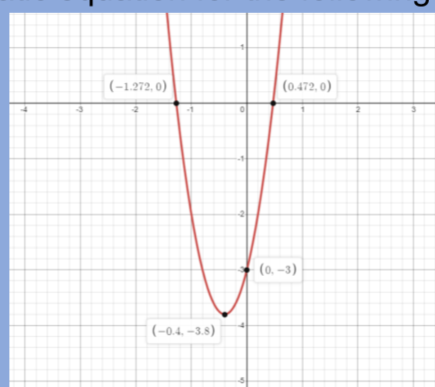
Warm-up

2.) With your group, compare the steps you took and write down similarities and differences.



Discovery

1.) Alex wrote a quadratic equation for the following graph in factored form.



He got y=(x-.472)(x+1.272).When he graphed it it didn't quite match up with the graph he was given. With your group, figure out where he went wrong.

Discovery

2.) With your group, convert Alex's fixed equation into standard form.

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

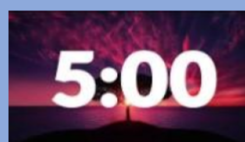
Welcome!

Quadratics – Day 9

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



Warm-up

1.) Draw the motion of a ball that is thrown

2.) What represents the starting point of the ball and what represents the ending point of the ball?

3.) What represents the highest point of the ball?

Warm-up

1.) Draw the motion of a ball that is thrown

2.) What represents the starting point of the ball and what represents the ending point of the ball?

3.) What represents the highest point of the ball?

Discovery

Kerry is kicking a ball in the air as high as she can. Her best kick is represented by the function

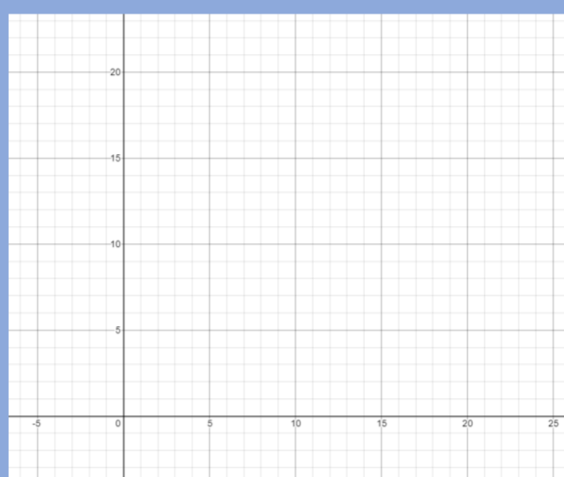
$$h(t) = -16t^2 + 35t + 1$$

1.) What does the variable h stand for?

2.) What does the variable t stand for?

Discovery

3.) Plot the ball on a coordinate grid.



Discovery

4.) Guessing time:

a.) What could $-16t^2$ mean? Why do you think so?

b.) What could +35t mean? Why do you think so?

c.) What could +1 mean? Why do you think so?

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

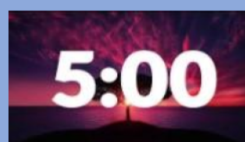
Welcome!

Quadratics – Day 10

Entrance Instructions

1.) Make sure you have paper and a writing utensil by your side

2.) Begin the warm-up! :D



Warm-up

Why should we guess?

How do you feel when you guess?

Warm-up

Discovery

Kerry is kicking a ball in the air as high as she can. Her best kick is represented by the function:

$$h(t) = -16t^2 + 35t + 1$$

1.) How high does she kick the ball?

2.) how car does the ball go?

Discovery

3.) Kerry tries to beat her current record. She kicks the ball at 34 feet per second and 2 feet off the ground.

a.) Write the equation that represents this kick.

b.) Does this kick beat her current record?

Closing

1.) Complete the exit questions.

2.) When you answer as much as you can, rip it off and turn it into this period's "exit ticket" bin.

Appendix F

Participation Spreadsheet

Participation Spread sheet

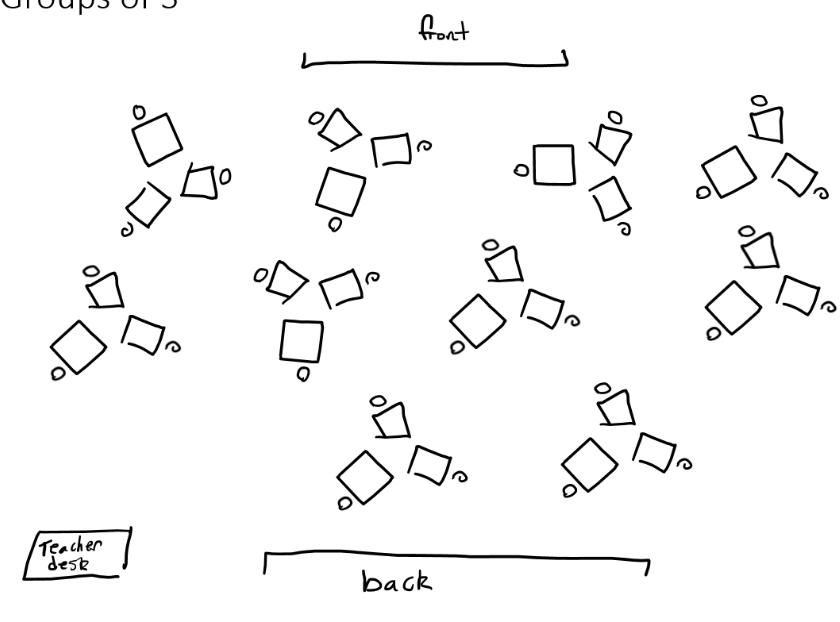
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Group A										
Tim										
Erika										
Ben										
Htoo										
Group B										
Sean										
Linda										
Abdi										
Marco										
Group C										
Group D										

Appendix G

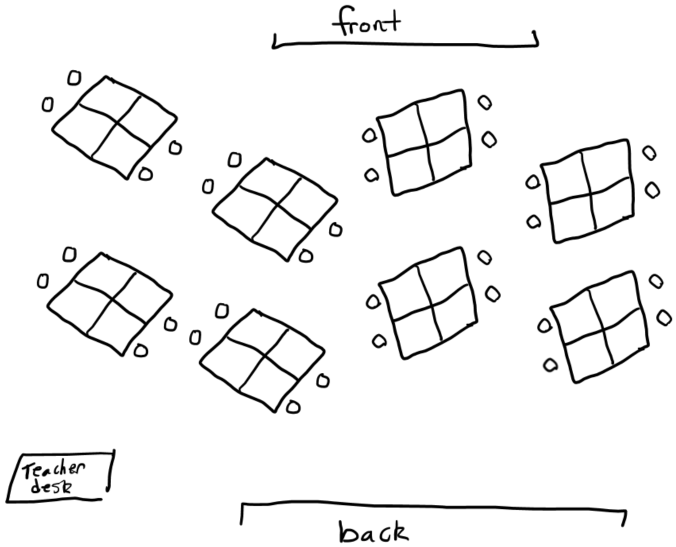
Seating Arrangements

Seating Arrangements

Groups of 3



Groups of 4



Groups of 5