# An Introduction to Quadratic Functions using the 5E Instructional Model

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## Abstract

Student-centered learning has been shown to increase student's engagement and overall achievement in the classroom. The 5E instructional model is one way for teachers to implement student-centered instruction into their classrooms. This model allows for students to engage, explore, explain, elaborate and evaluate throughout the learning process. This curriculum project presents four sequential Algebra I lessons that incorporate the 5E instructional model to teach an introduction to quadratic functions. The curriculum was designed to be aligned with the NYS Next Generation Mathematics Standards for Algebra I. The answer key for all lesson materials and activities is included in the appendix of this project. By using these lessons, mathematics teachers can be supported in incorporating a student-centered approach in their classroom in order to maximize student learning and engagement.

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## Introduction

Teachers want their students to succeed in the classroom and research shows, that using student-centered instruction maximizes student learning and achievements (Eronen & Kärnä, 2018). There are different ways to implement student centered instruction in the classroom, and one of them is the 5E instructional model. The 5E instructional model includes five areas of focus: engage, explore, explain, elaborate, and evaluate. The purpose of this curriculum project is to support teachers in developing a student-centered classroom by utilizing the 5E instructional model. Each of the four lessons also incorporate instructional technology which provides the opportunity for more student engagement in the learning process. These lessons can be used in an Algebra I course to introduce quadratic functions. Students will be introduced to quadratic functions in lesson 1, learn to graph parabolas in lesson 2, discover the transformations of quadratic functions in lesson 3 and finally, apply their knowledge to solve real-world problems involving quadratic functions in lesson 4. It is the authors hope that teachers are able to increase student engagement and achievement in the mathematics classroom through the use of the 5E instructional model.

## Literature Review

In recent years, more educators are incorporating student-centered instruction over the traditional approach that has been used in the past. Traditional teaching methods where teachers provide direct instruction for new material, recognizes the teacher as the dominant authority of the class (Omotayo & Adeleke, 2017). When the teacher is viewed as the dominant authority, students take a back seat in the learning process and it becomes harder for them to develop their own understanding of what is being taught to them. This is why student-centered instruction is becoming more relevant in today's classrooms. Based on recent research studies, "the focus has

been on collaborative problem-based methods for improving the learning process" in the mathematics classroom and an even greater focus on students' control over their own learning (Eronen & Kärnä, 2018, p. 3).

**Student-Centered Learning**

There are many different interpretations of student-centered learning but one of them can be done by using lessons based on self-guidance, the use of technology, and minimalist instruction. By incorporating self-guidance into lessons, "many have reported that the feeling of self-guidance improves learners' meta-cognitive skills and ability to evaluate their own work" (Eronen & Kärnä, 2018, p. 12). Minimal instruction is very different from the traditional teaching approach in that teachers are required to take a step back and allow students to engage in a lot of the discovery and learning process themselves. Additionally, technology provides learners with a lot of freedom when it comes to self-directing their own actions in the learning process and determining when, where and how to learn (Eronen & Kärnä, 2018). It has been shown students become more aware of their own learning with self-directed informed instruction (Eronen & Kärnä, 2018).

**5E Instructional Model**

Several approaches that support student centered learning include discovery learning, problem-based learning, inquiry-learning, experiential learning and constructivist learning (Eronen & Kärnä, 2018). One approach to student-centered instruction used in the mathematics classroom is the 5E instructional model. Table 1 below presents the 5E components and their description. The five components engage and invest students in what they are learning and connects student interest and effort. It has been implied from research studies that, "the more

individuals become interested in a subject, the more effort they will put into their learning" (Omotayo & Adeleke, 2017, p. 16).

Table 1: The 5E Instructional Model Components (Bybee et al., 2006).

| Stage | Summary |
|---|---|
| Engagement | The teacher activates the learners' prior knowledge and engages them in the new concept through a short activity (i.e. a warm-up or do now). The activity builds connections between what the learner knows and what they are about to learn. |
| Exploration | The exploration process provides students with an activity where they are using prior knowledge to generate new ideas and make meaning of their own learning. |
| Explanation | The explanation stage allows the learner to demonstrate their understanding of the new material. An example from the teacher at this stage may be helpful in guiding the learning to make their explanation. |
| Elaboration | The learners' understanding of new material is extended upon and students are given the chance to deepen their knowledge. Students may participate in additional activities where they will apply their knowledge. |
| Evaluation | The evaluation stage allows the learner to assess their understanding. This also provides teachers with a way to evaluate student progress made throughout the lesson. |

**Technology**

Raines and Clarke (2011) showed that, "incorporating and using technology in the teaching of mathematics can encourage students to become active participants in the classroom" (p. 1). When students become active participants in the classroom, it becomes a student-centered learning environment and students are able to make more meaning of what they are learning. Not only do students have access to graphing calculators, most students now have access to their own

technological device, whether it be an i-pad, laptop or computer. Research shows that technology is yet another solution that educators can use in the classroom to enrich and change the traditional method of teaching (Eronen & Kärnä, 2018). It adds to the student-centered learning approach by providing students with opportunities to determine when, where and how to learn. This gives students control over their own learning which can increase their intrinsic motivation toward learning mathematics and their identity as math learners' (Eronen & Kärnä, 2018).

By incorporating activities different from conventional paper and pencil work, students may be more motivated and engaged in learning (Raines & Clark, 2011). Another important aspect of incorporating technology is that students are able to receive live feedback which allows them to rectify their mistakes on the spot, rather than waiting for the teacher to grade their work. This is very helpful in the exploration part of a lesson. A component of not only the 5E model but the student-centered learning approach states that, "errors are not avoided but used for instruction" (Eronen & Kärnä, 2018, p. 4). With that being said, incorporating live feedback allows students to enter answers without feeling discouraged or confused when they do not know the correct answer, they are simply able to correct their work and learn from their mistakes. Another aspect of providing opportunities for students to engage in technology throughout the lessons is students will also increase their computational thinking skills.

This curriculum project presents lessons based on the 5E instructional model as each of the four lessons incorporate the five components of engagement, exploration, explanation, elaboration, and evaluation. The activities were designed for students to exercise principles promoted in a student-centered learning classroom and allows for students to be provided with new material that is scaffolded while learning through inquiry-based activities. This project also incorporates the use of instructional technology in each lesson by providing students with the

opportunity to engage in interactive technological activities on different computer based programs such as quizizz.com, polypad.com, and desmos.com. Overall, the resources provided in this project can be used by other teachers to support them in in transitioning into more student-centered learning approaches.

## Curriculum

**Lesson 1 Overview** Lesson 1 of the curriculum plan will be an introductory lesson to quadratic functions. Students will be introduced to new vocabulary terms and what a quadratic function is and what it looks like when graphed. Students will start off with an engaging do now where they will explore the concept of a quadratic graph. Then students will learn new vocabulary with an interactive notebook. Finally students will complete a desmos activity where they will practice using the vocabulary that was learned in the lesson.

**How will the lesson engage students using the 5E model?**

| | |
|---|---|
| Engage | Students will engage with interactive materials to identify key features of a quadratic function. Students will complete the do now through desmos, the notes will be copied through the use of an interactive notebook online and the closing activity will be through desmos as well. |
| Explore | Students will begin by exploring the concept of a quadratic function by being asked to draw a graph that represents the path of a ball being thrown for their warm-up. The warm-up activity will be completed through an online interactive website; desmos.com |
| Explain | Students will explain their drawing in the do now activity. Students will have an opportunity to explain their reasoning to the class during a class discussion prior to introducing the new vocabulary. Students will use new vocabulary learned about quadratics in their explanations. |
| Elaborate | Students will elaborate on their understanding of the quadratic vocabulary words by completing the desmos activity. This will further develop their mathematical literacy in regards to quadratic functions. They must be able to understand the terms to complete the tasks on the desmos slides. |

| | |
|---|---|
| Evaluate | Students will evaluate their own understanding of the new vocabulary words with the exit ticket. The exit ticket is the last slide of the desmos activity. |

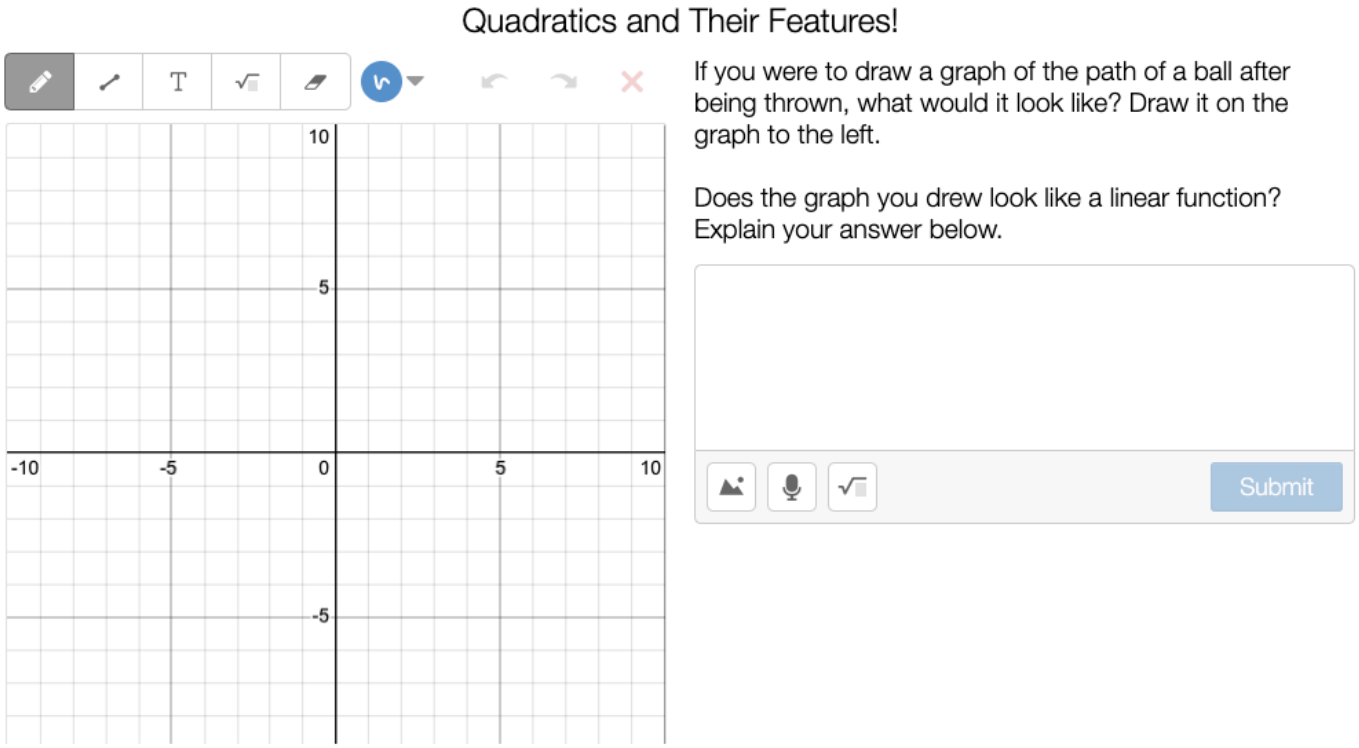
**Lesson Plan**

| | |
|---|---|
| Course: | Algebra I |
| Lesson Title/Topic: | Introduction to Quadratic Functions |
| Standard(s) Addressed: | AI-F.IF.4. For a function that models a relationship between two quantities: i) interpret key features of graphs and tables in terms of the quantities; and ii) sketch graphs showing key features given a verbal description of the relationship. |
| Learning Target(s) | I can identify key features of a quadratic function. |
| Explore/Warm-up | Students will join a desmos activity where they will complete the do now question. The do now asks them: "If you were to draw a graph of the path of a ball after being thrown, what would it look like? Draw it on the graph to the left.<br>Does the graph you drew look like a linear function? Explain your answer below."<br>By using desmos, this allows me to quickly assess all students' answers. This also allows for an interactive introduction to the lesson because students are all asked to create their own graph. Students are engaged through desmos, exploring the concept of quadratic graphs and also expected to explain their reasoning. After students submit their answers on desmos, we will have a class discussion where students explain what their graph looked like and why. |
| Mini-Lesson | The class discussion will bring us to the mini lesson of the day. Students will be introduced to quadratic functions and their features with an interactive notebook. Students will fill in the blanks on their google slides as I introduce the vocabulary words. |

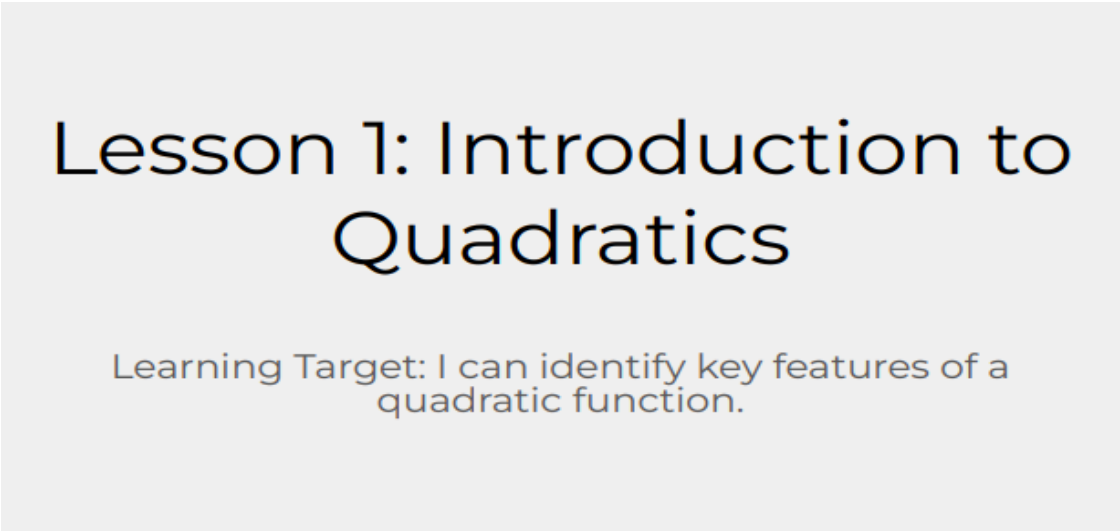
| | |
|---|---|
| | After going over vocabulary, students will complete the three examples on the following slides where they will locate the vertex, x-intercepts, y-intercept, max or min, and axis of symmetry.<br>Students will turn their interactive notebook into the google classroom to be assessed. |
| Activity/Practice: | After completing the interactive notebook, students will then join the desmos activity called “Parabolas Key Features Activity”. Students will use their new knowledge of vocabulary to practice identifying key features of parabolas. |
| Closure: | Students will complete the activity which includes a closure and summary slide that asks students to rate how well they understood the math they learned today and how they felt about it. They will also be given a chance to elaborate on their feelings. |
| Assessment: | Students will be assessed through their responses on the do now, the interactive notebook as well as the closing desmos activity. Students will also be assessed informally through their responses to my questions throughout the lesson. |
| Resources: | Desmos do now slide, interactive notebook slides, desmos closing activity, 1:1 device for students. |

**Lesson 1 Materials**

Do Now Slide: https://teacher.desmos.com/activitybuilder/custom/64038c96cea114a93388ecb8

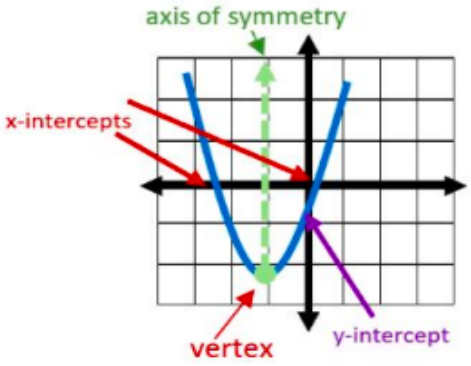



Interactive Notebook Slides:
https://docs.google.com/presentation/d/1AJPRzvNQVb9f52kfq4dL7V07v6ua0K9eNfcXKOc2aW8/edit?usp=sharing

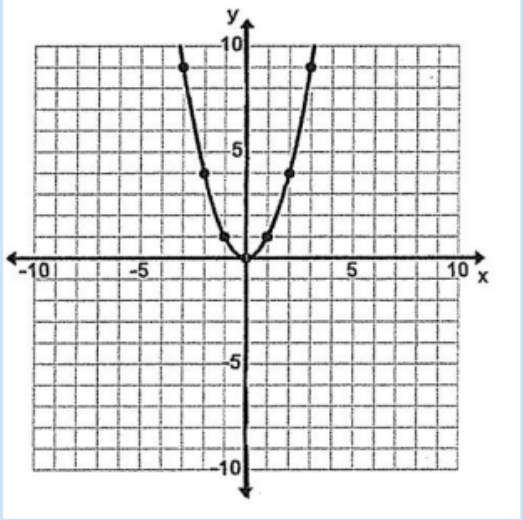


**Key Vocabulary:**

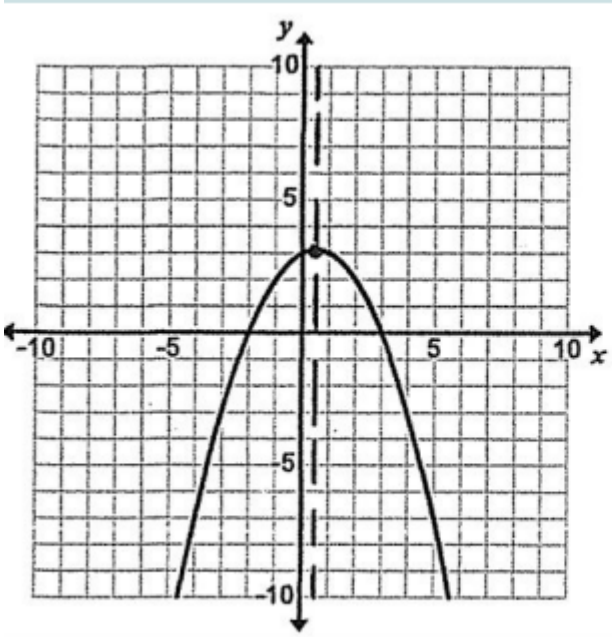
- A function where the highest exponent is squared is called a _____ function.
- The graph of a quadratic function is a U shaped curve called a _____.
- The highest or lowest point of the graph is called the _____. It can also be considered the _____ _____.




- The _____ _____ _____is the vertical line that passes through the vertex and divides the graph into two mirror images.
- The x-values where the graph crosses the x-axis are called the _____ or the _____.
- The point where the graph crosses the y-axis is called the _____.




1. **Vertex:**
2. **Roots/x-intercepts:**
3. **Max or Min?**
4. **Axis of Symmetry:**
5. **y-intercept:**

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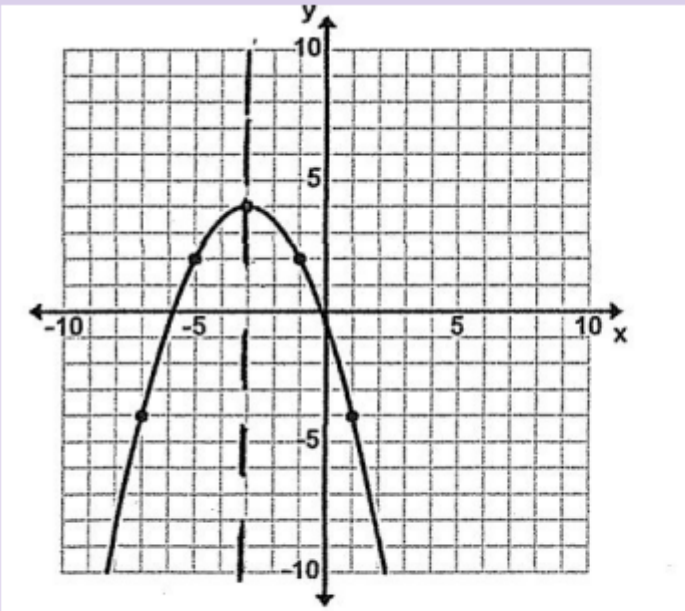
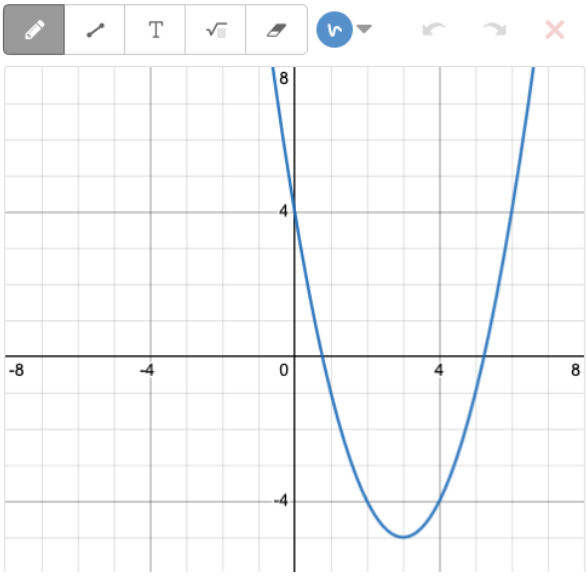



1. **Vertex:**
2. **Roots/x-intercepts:**
3. **Max or Min?**
4. **Axis of Symmetry:**
5. **y-intercept:**

Desmos Activity: https://teacher.desmos.com/activitybuilder/custom/64039195bdff7a9a7c4fc104

## "Turning Point"




During Polygraph: Parabolas, Edwin asked this question:

"Is your parabola's turning point below the $x$-axis?"

(1) Use the sketch tool to indicate what Edwin is describing as the parabola's "turning point."

(2) What other word or phrase could we use for "turning point"?

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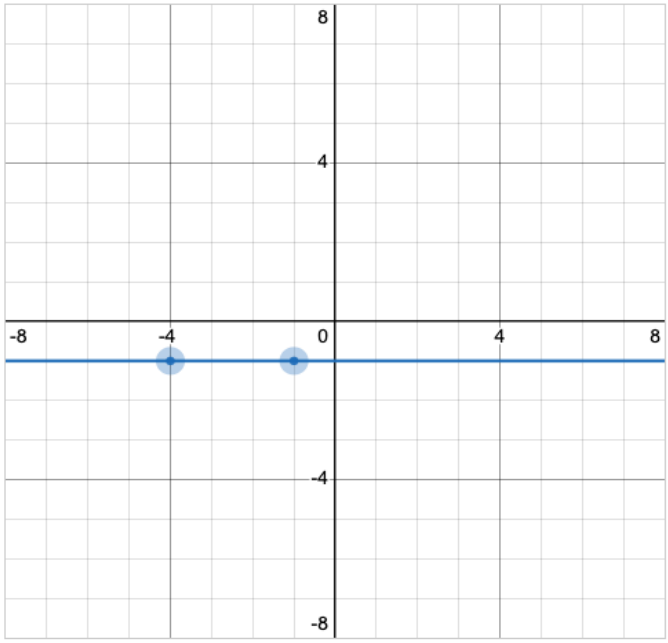
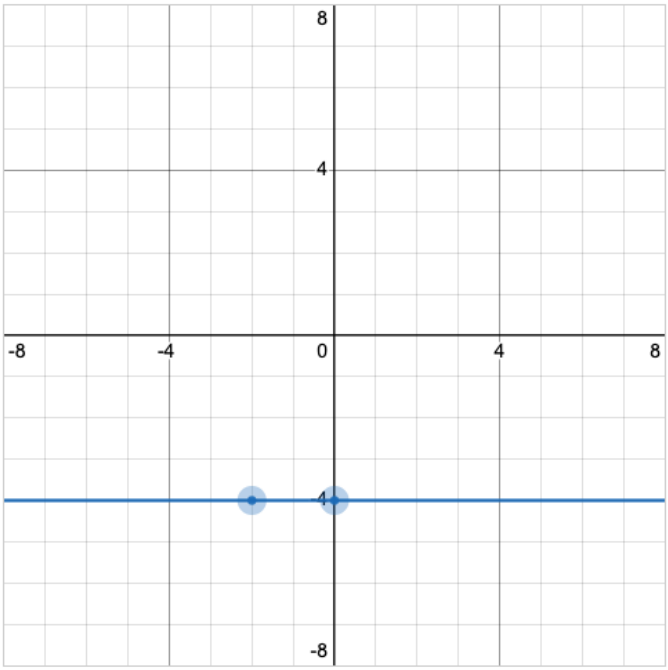
## Vertex




Mathematicians call this "turning point" the VERTEX.

Drag the blue points to create a parabola whose vertex is on the $y$-axis.

## "Smile"




During Polygraph: Parabolas, Sarah asked this question:

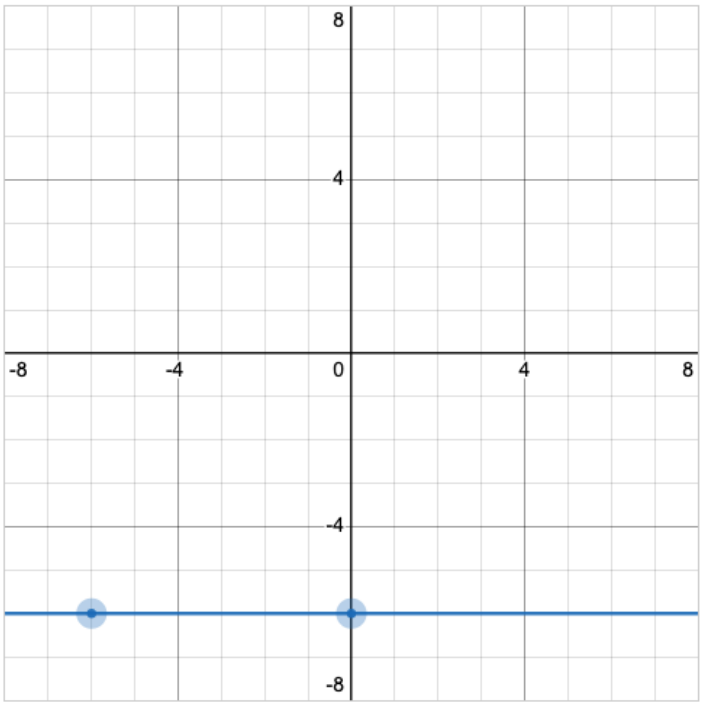
"Does your parabola look like a smile?"

(1) Drag the blue points to show what the graph could have looked like if the answer was "yes."

(2) What other word or phrase could we use for "looks like a smile"?

Share With Class

## Concave Up, Concave Down

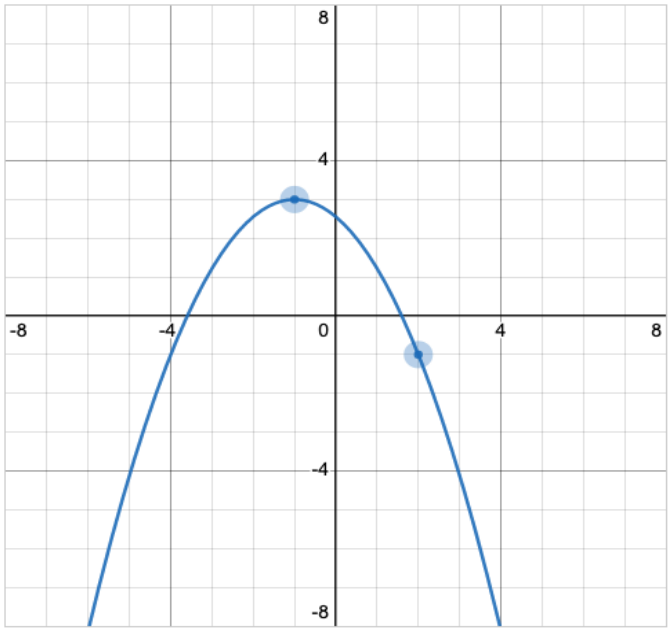



Instead of saying "looks like a smile," mathematicians say CONCAVE UP.

Likewise, instead of "looks like a frown," mathematicians say CONCAVE DOWN.

Drag the blue points to create a concave down parabola with vertex $(4,-2)$.

## Intercepts

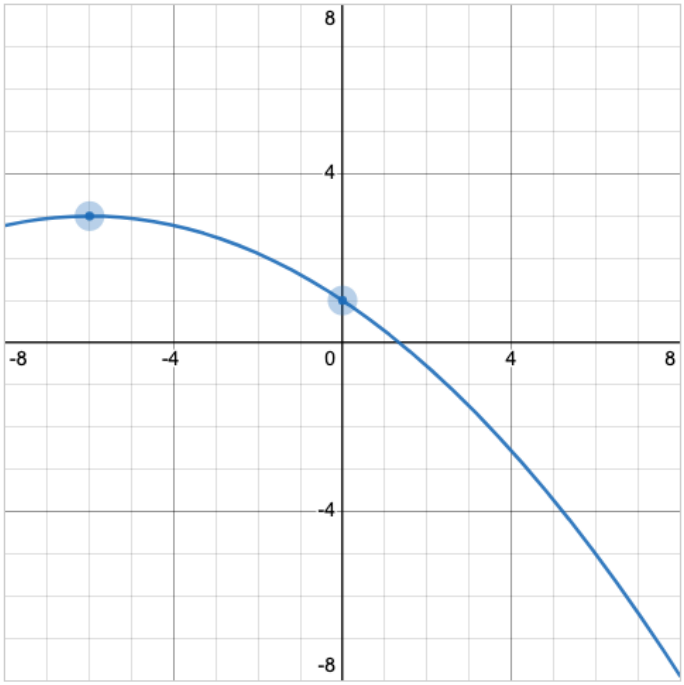



We can make the phrase "touches the middle line twice" more formal and more precise by asking:

"Does your parabola have two $x$-intercepts?"

Drag the blue points to create a parabola with EXACTLY ONE $x$-intercept.

## "Cut the Parabola in Half"




During Polygraph: Parabolas, Miguel asked this question:

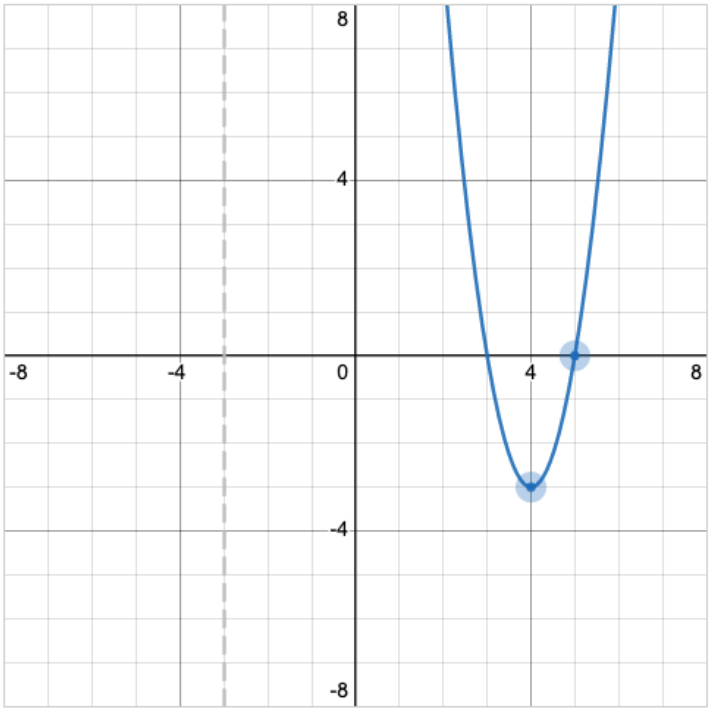
"Does the $y$-axis cut the parabola in half?"

(1) Drag the movable points to show what the graph could have looked like if the answer was "yes."

(2) What other word or phrase could we use for "cut the parabola in half"?

Share With Class

## Line of Symmetry



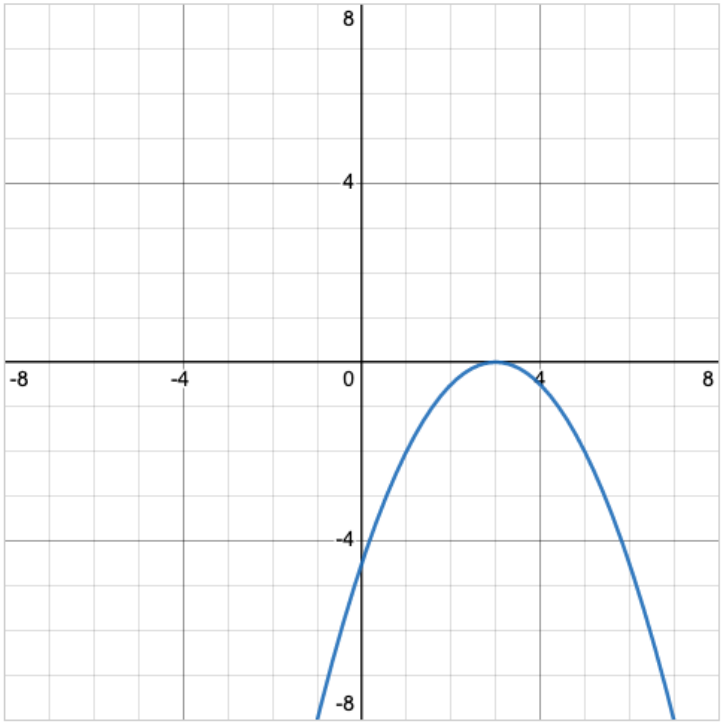

Mathematicians might rephrase Miguel's question as:

"Is your parabola SYMMETRIC across the $y$-axis?"

They might also refer to this as the LINE OF SYMMETF

Drag the blue points to create a parabola whose line of symmetry is the gray dotted line shown here.

## Challenge #1

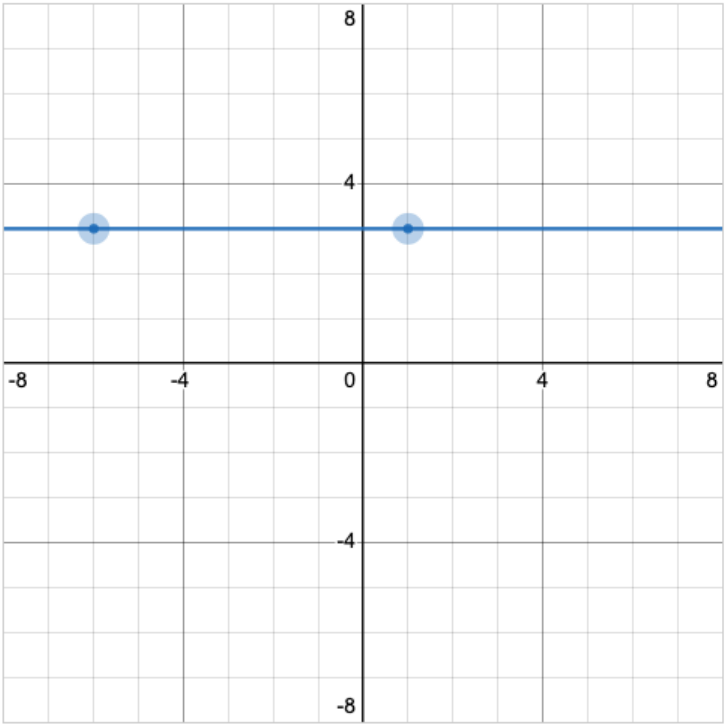



Which of these statements are true for the parabola shown here? Select all that apply.

*(Select all that apply.)*

- [ ] Vertex on the $y$-axis
- [ ] Concave down
- [ ] One positive $x$-intercept
- [ ] One negative $y$-intercept
- [ ] Line of symmetry at $y = 3$

## Challenge #2




Drag the blue points to create a parabola that meets these requirements:

(1) Vertex below the $x$-axis
(2) Concave up
(3) One positive $x$-intercept
(4) One negative $x$-intercept
(5) Line of symmetry at $x = 2$

## Lesson Wrap-Up

How well did you understand the math today?

How did you feel about learning math today?

Drag the point to show how today went.

Please elaborate on your responses below.

Submit

**Lesson 2 Overview** Lesson 2 of my curriculum plan will be on graphing quadratic functions in standard form. Students will start off with an engaging do now where they will review some key vocabulary from the previous lesson. Then students will learn how to graph a quadratic function and practice this concept with a relay activity. Finally students will complete the "two truths and a lie" activity where they will create their own challenge similar to the do now that was completed in the beginning of the lesson.

**How will the lesson engage students using the 5E model?**

| | |
|---|---|
| Engage | Students will be engaged throughout the entire lesson through the use of interactive activities. Students will complete the do now through desmos to engage them in the topic through a fun activity and then students will engage in a relay activity to practice the new skill they learned. |
| Explore | Students will explore a quadratic graph by trying to figure out which statement of three is a lie. At the end of the lesson they will create their own two truths and a lie activity as well. |
| Explain | Students will explain their answer to the do now question. Students will also explain their reasoning when creating their own two truths and a lie activity for the exit ticket. |
| Elaborate | Students will elaborate on their choice during the do now activity when they state which line is the lie about the parabola. |
| Evaluate | Students will get a chance to evaluate their partner's exit ticket and figure out which statement is a lie. Students will also evaluate each parabola on the guided note sheet to find the vertex, axis of symmetry and the roots. |

**Lesson Plan**

| | |
|---|---|
| Course: | Algebra I |
| Lesson Title/Topic: | Graphing Quadratic Functions |
| Standard(s) Addressed: | AI-F.IF.4. For a function that models a relationship between two quantities: i) interpret key features of graphs and tables in terms of the quantities; and ii) sketch graphs showing key features given a verbal description of the relationship. |

| | |
|---|---|
| Learning Target(s) | I can graph a quadratic function in standard form. |
| Introduction/Warm-up | To start off the lesson, students will join the online desmos activity where they will be asked to figure out which of the three statements about the parabola shown is a lie. Then they will be asked to explain their answer. I can see all of the answers so I might show one on the screen and make it anonymous and go over it with the class. This will be a review of the new vocabulary that was learned in the previous lesson. |
| Mini-Lesson | The mini lesson will be on graphing quadratic functions that are in standard form. The students will receive a guided note sheet to go along with the lesson. I will introduce to students what standard form of a quadratic equation looks like as well as the steps to graphing it. I will model example #1 which is the parent quadratic function. Students will complete the example #2 with my guidance and then example #3 independently. Once I check that all students completed example #3 correctly, they can move on to the relay activity. |
| Activity/Practice: | Students will practice their new knowledge of graphing quadratic functions with a relay activity. They will be arranged in groups of 6 and each student in the group will get their own chance to graph a quadratic function. Once they complete their graph, they will bring it up to me to get checked and then begin the next graph. Everyone in the group will get a chance to complete a graph. |
| Closure: | To end off the lesson, students will complete their own two truths and a lie activity, that is similar to what we did for the do now. They will get a coordinate plane where they will graph a function and then create two true statements and one lie about the parabola that they graphed. They will then trade papers with a partner and their partner will figure out which statement is the lie. |
| Assessment: | Students will be assessed through their responses on the do now, the relay activity as well as the exit ticket activity.<br>Students will also be assessed informally through their responses to my questions throughout the lesson. |

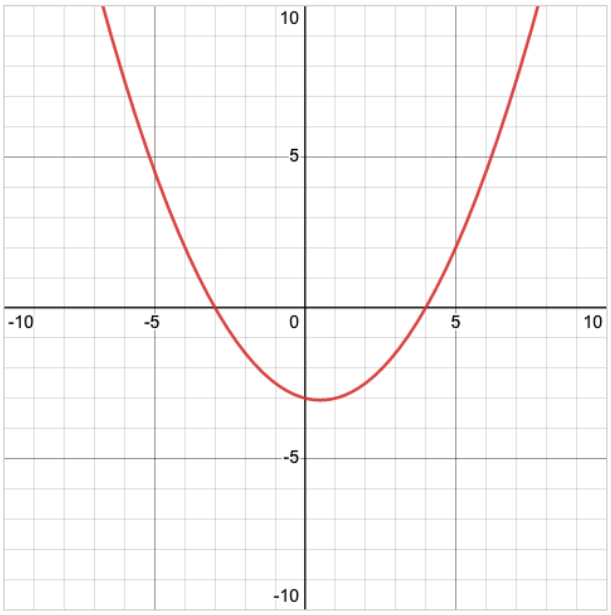
| | |
|---|---|
| Resources: | Desmos do now slide, guided note sheet, relay activity, exit ticket, 1:1 device for students. |

**Lesson 2 Materials**

Do Now Desmos Activity:

https://teacher.desmos.com/activitybuilder/custom/6417468c75fc392e18018af1

Do Now: Where's the Lie?




Here are three statements that Tiana wrote about this parabola.

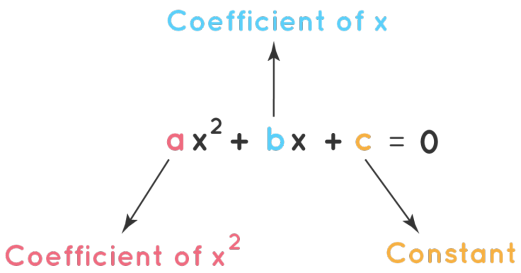
One of the statements is a lie. Which is it?

- The parabola has a line of symmetry at $x = 0$.
- The parabola has exactly one positive $x$-intercept.
- The parabola is concave up.

Name:_____Date:_____Period:_____

Learning Target: I can graph a quadratic function in standard form.

## Standard Form of a Quadratic Equation




Steps to graphing a Quadratic Equation:

1. Type the equation into y = on your graphing calculator
2. Look at the table and identify the VERTEX.
3. Copy down the table of values centered around the vertex.
4. Plot all points that fit on the graph and connect with a curved U.

Example #1: Graph the equation y = $-x^2 - 4x + 5$

| x | y |
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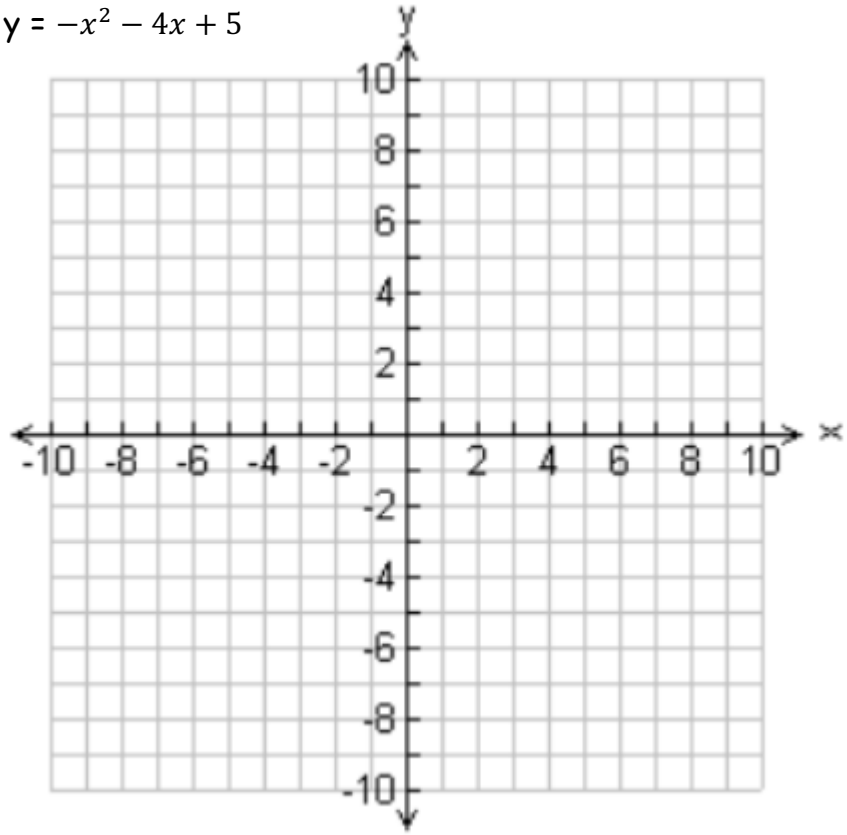
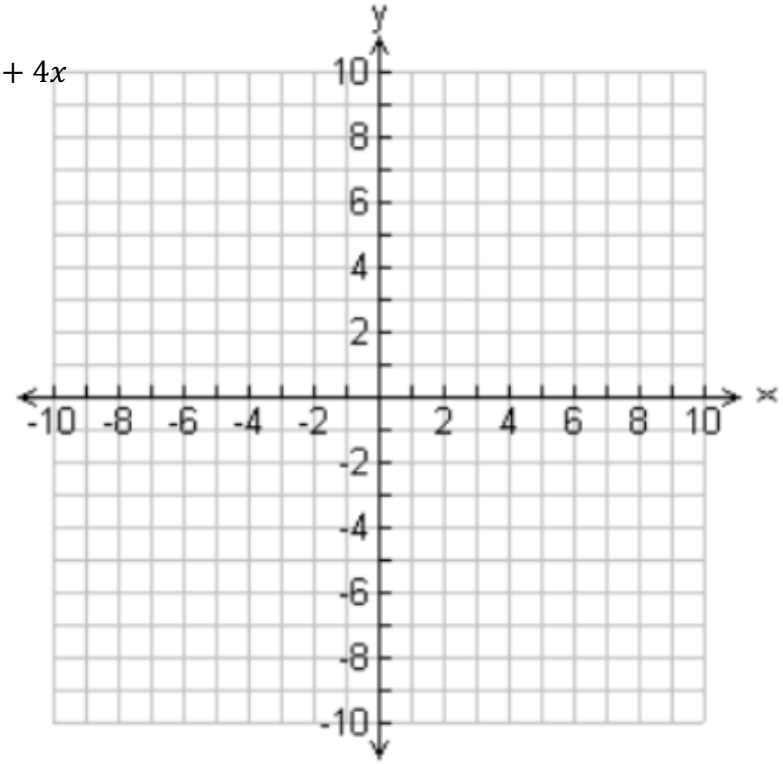



Vertex: Axis of Symmetry: Roots:

Example #2: Graph the equation y = $2x^2 + 4x$

| x | y |
|---|---|
| | |
| | |
| | |
| | |
| | |




Vertex: Axis of Symmetry: Roots:

Example #3: Graph the equation y = $-x^2 - 2$

| x | y |
|---|---|
| | |
| | |
| | |
| | |
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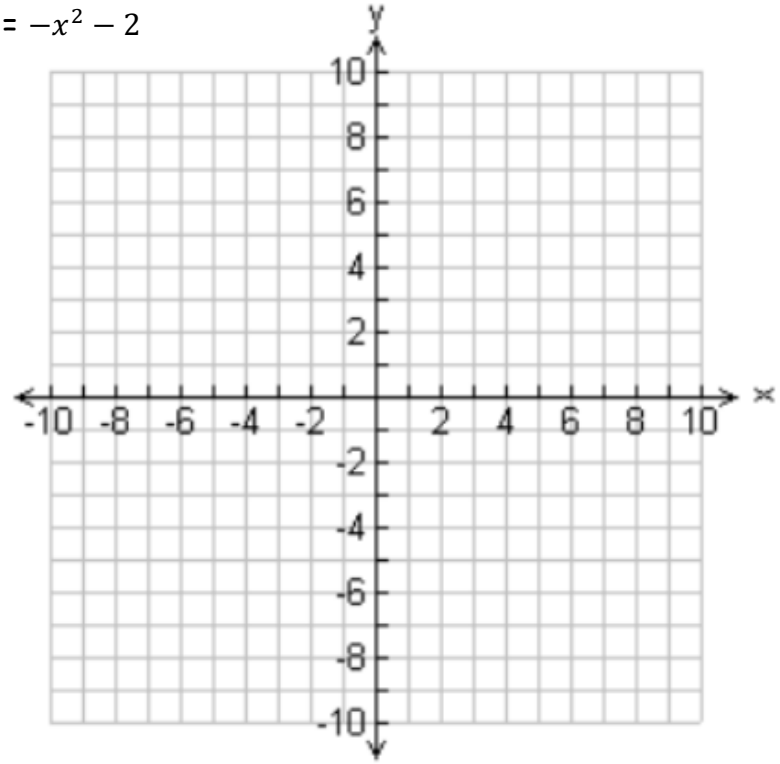



Vertex: Axis of Symmetry: Roots:

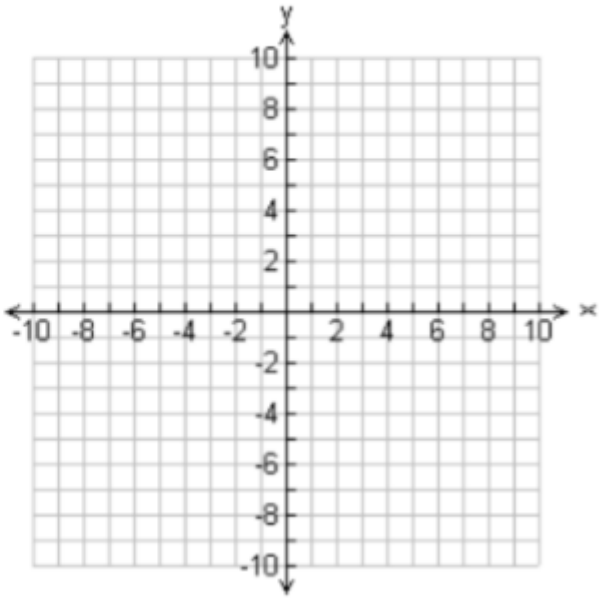
## *Relay Activity: Graph Quadratics in Standard Form*

**Round 1**

Graph $y = x^2 - 2$

| x | f(x) |
|---|---|
| | |
| | |
| | |
| | |
| | |

vertex →



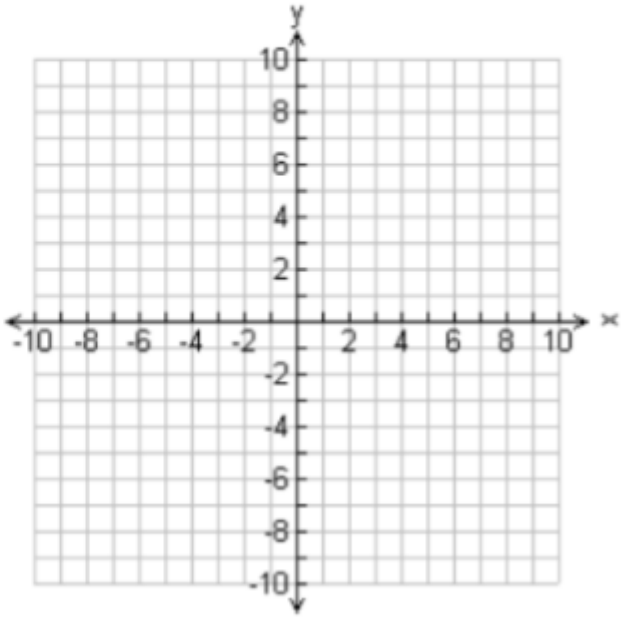

## *Relay Activity: Graph Quadratics in Standard Form*

**Round 2**

Graph $f(x) = -x^2 + 2x + 2$

| x | f(x) |
|---|---|
| | |
| | |
| | |
| | |
| | |

vertex →



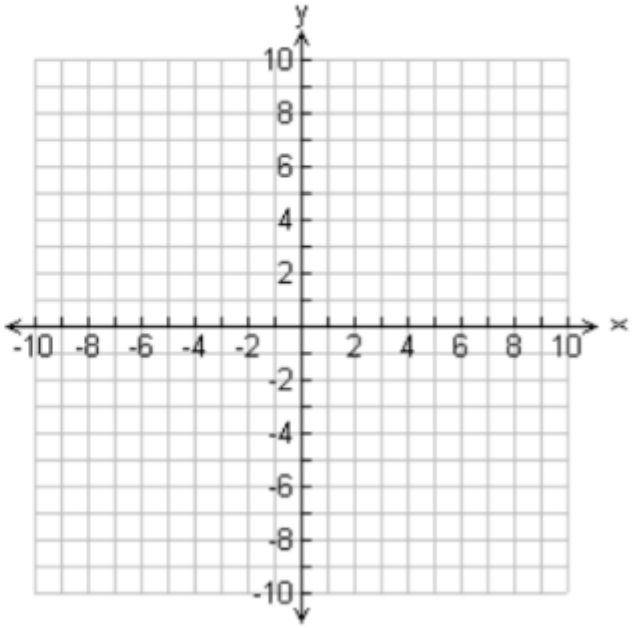
## *Relay Activity: Graph Quadratics in Standard Form*

**Round 3**

Graph $f(x) = x^2 - 4x + 3$

| x | f(x) |
|---|---|
| | |
| | |
| | |
| | |
| | |

vertex →



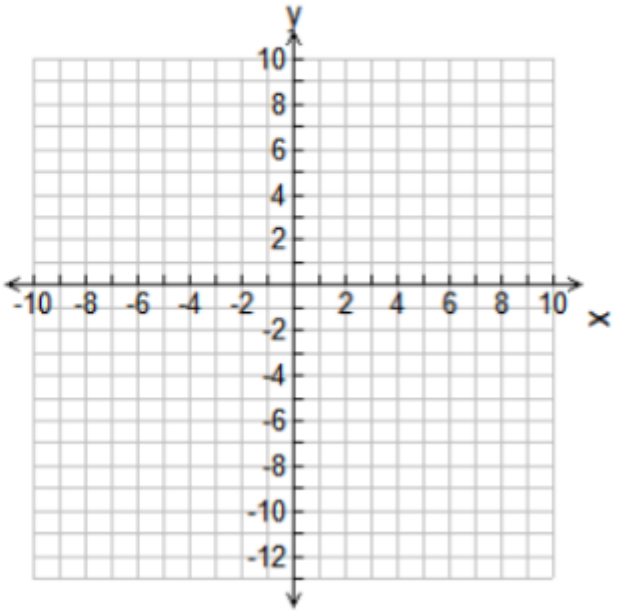

## *Relay Activity: Graph Quadratics in Standard Form*

**Round 4**

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

| x | f(x) |
|---|---|
| | |
| | |
| | |
| | |
| | |

vertex →



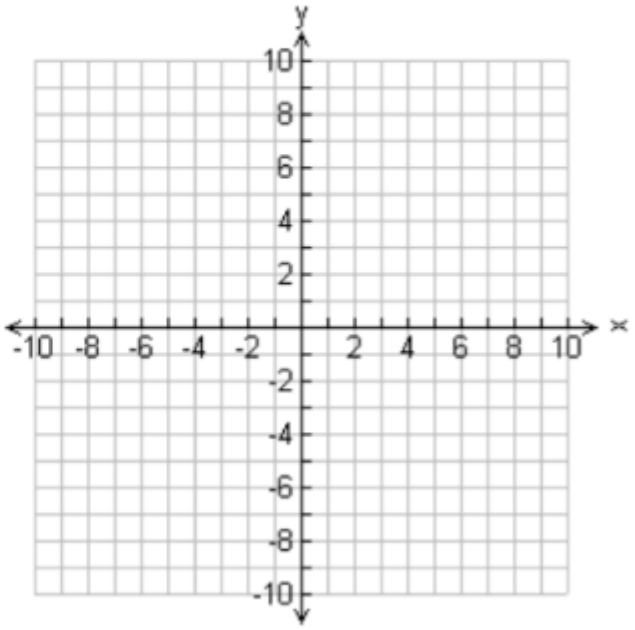
## *Relay Activity: Graph Quadratics in Standard Form*

**Round 5**

Graph $f(x) = -3x^2 + 12x - 5$

| x | f(x) |
|---|---|
| | |
| | |
| | |
| | |
| | |

vertex →




## *Relay Activity: Graph Quadratics in Standard Form*

**Round 6**

Graph $y = -\frac{1}{2}x^2$

| x | f(x) |
|---|---|
| | |
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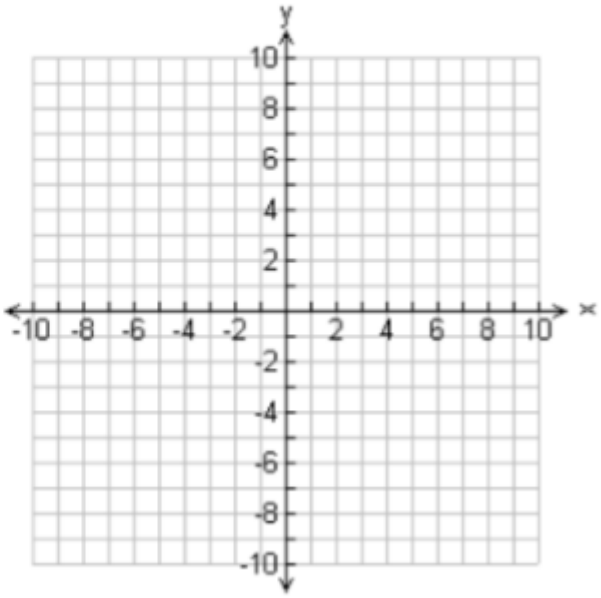
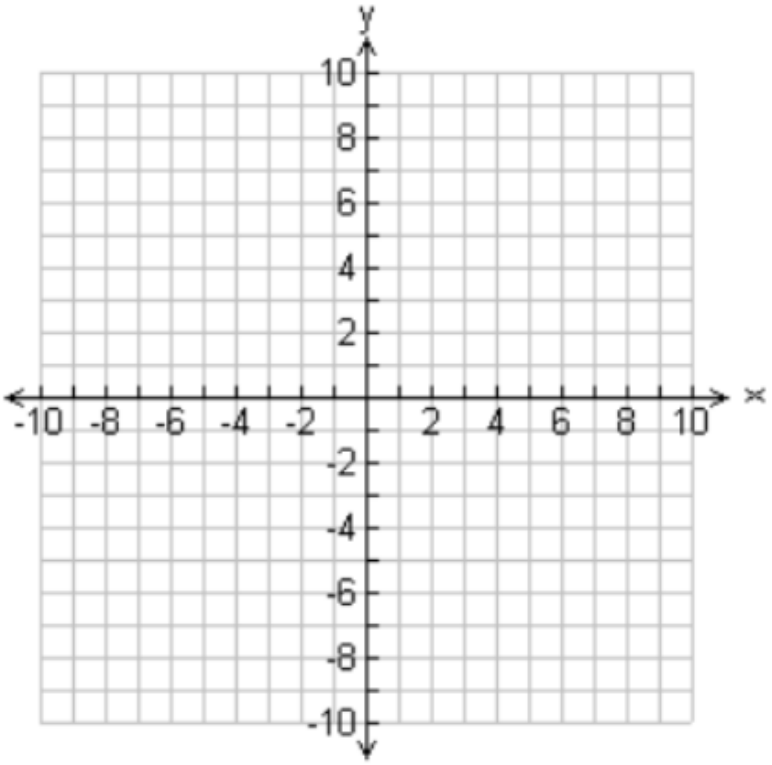
| | |
| | |
| | |

vertex →



Name:_____Date:_____Period:_____

Exit Ticket: Graph a parabola on the coordinate plane provided. Then write down three statements about your parabola; two truths, and one lie!




1.

2.

3.

**Lesson 3 Overview** Lesson 3 of the curriculum plan will be an introduction to shifting quadratic functions. Students will discover how the values of a, h and k, transform the quadratic function $f(x) = a(x-h)^2 + k$. Students will use a resource called polypad that I have created to go along with a guided worksheet. Throughout the lesson, students will complete the guided notes while using the polypad to discover the rules of transforming independently.

**How will the lesson engage students using the 5E model?**

| | |
|---|---|
| Engage | Students will engage with an interactive website called polypad, throughout the entire lesson to identify how the values of a, h, and k transform a quadratic function. |
| Explore | Students will explore the rules of transforming quadratic functions by playing with the variable sliders on the polypad to discover the shift in the parent quadratic function. |
| Explain | Students will explain how a, h, and k change the quadratic function with their guided worksheet. They will answer guided questions to encourage them to discover the rules on their own while also using key vocabulary from the previous lessons. |
| Elaborate | Students will elaborate on their findings by answering the conclusion questions on their guided worksheet. This is where they will conclude what exactly they discovered while using mathematical literacy to further their understanding of quadratic functions. |
| Evaluate | Students will evaluate their own understanding of the transformation rules with the conclusion questions. After having a class discussion, students will assess their understanding of the learning target and if they were able to reach the learning target. |

**Lesson Plan**

| | |
|---|---|
| Course: | Algebra I |
| Lesson Title/Topic: | Shifting Quadratic Functions |
| Standard(s) Addressed: | **AI-F.IF.4.** For a function that models a relationship between two quantities: i) interpret key features of graphs and tables in terms of the quantities; and ii) sketch graphs showing key features given a verbal description of the relationship.<br><br>**AI-F.BF.3a.** Using f(x) + k, k f(x), and f(x + k): i) identify the effect on the graph when replacing f(x) by f(x) + k, k f(x), and f(x + k) for specific values of k (both positive and negative); ii) find the value of k given the graphs; iii) write a new function using the value of k; and iv) use technology to experiment with cases and explore the effects on the graph. |
| Learning Target(s) | I can describe how the constants a, h and k affect the graph of the quadratic function $g(x) = a(x-h)^2 + k$. |
| Warm-up | Students will answer the warm-up on their guided notes sheet. The warm-up will be questions on the parent quadratic function, so that when students begin the exploration they know what to compare the function to. |
| Exploration/Guided Questions | After completing the warm-up, students will begin the exploration process. They will have six equations and six graphs that they will have to match together using the polypad that was shared with them. By toggling with the values of a, h and k, they will discover and explore which graphs match with which equations. After they find the pairs, they will then have to provide evidence to explain their answers.<br>After completing the exploration activity, they will then continue toggling with the variable sliders on the polypad to complete the guided questions. The guided questions are provided to help guide students to the realization that a, h and k, all affect the parent quadratic function in 3 very distinct and unique ways. |

| | |
|---|---|
| Conclusion: | After completing the guided questions, students should come to the conclusion of how a, h and k, affect the parent quadratic function. After stating a summary of how those three variables affect the graph, they will then answer a question to apply their new knowledge. The second question can be answered however the students see fit, either by their knowledge of the new rules, or by using the polypad once again.<br>To close the lesson, we will have a class discussion on the rules of transforming quadratic functions where students will check their work. |
| Assessment: | Students will be assessed informally throughout the lesson as the teacher circulates the room to monitor students' work.<br>Students will also be assessed when their guided notes packet is collected at the end of the lesson. |
| Resources: | Polypad: https://mathigon.org/polypad/ad6MHfeyZhUSw<br>Guided notes packet |
| Course: | Algebra I |

Name:_____Date:_____Period:_____

Learning Target: I can describe how the constants a, h and k affect the graph of the quadratic function $f(x) = a(x-h)^2 + k$.

**Polypad:** https://mathigon.org/polypad/ad6MHfeyZhUSw

**Warm-up:** On the polypad you have the graph of a parent quadratic function shown on the coordinate plane. Please answer the following questions about the graph.

a. What are the coordinates of the vertex?

b. Does the graph have a maximum or minimum?

c. What is the equation of the axis of symmetry?

d. What are the roots of the graph?

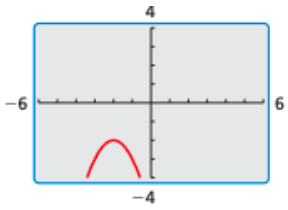
---

**Exploration:** Using the polypad that was shared with you, play around the with values of a, h, and k, to match the following quadratic equations with their graphs. Explain your reasoning using evidence from the polypad.

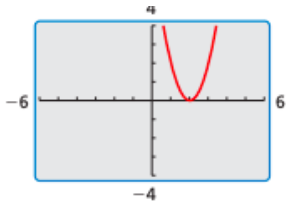
**a.** $g(x) = -(x-2)^2$ **b.** $g(x) = (x-2)^2 + 2$ **c.** $g(x) = -(x+2)^2 - 2$

**d.** $g(x) = 0.5(x-2)^2 - 2$ **e.** $g(x) = 2(x-2)^2$ **f.** $g(x) = -(x+2)^2 + 2$

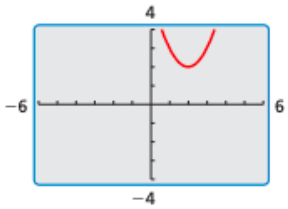
A.



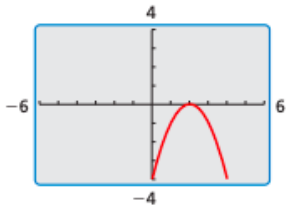

B.



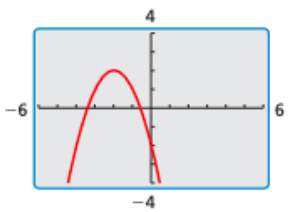

C.



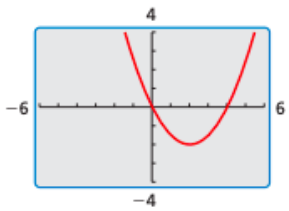

D.




E.




F.



| | |
|---|---|
| A: | B: |
| C: | D: |
| E: | F: |

**Guided Questions:**

Part I: How does "**a**" affect the graph of the quadratic?

- What was the visual effect when you changed the value of a?
- What happened when a was negative?
- What happened when a was positive?
- What did the graph look like when $a > 1$ versus $0 < a < 1$ ?
- Did the vertex change?

Part II: How does "h" affect the graph of the quadratic?

- What was the visual effect when you changed the value of h?
- What happened when h was negative?
- What happened when h was positive?
- Did the vertex change?

Part III: How does "k" affect the graph of the quadratic?

- What was the visual effect when you changed the value of k?
- What happened when k was negative?

- What happened when k was positive?

- Did the vertex change?

**Conclusion**

1. In a brief summary please sum up how a, h and k, transform the graph of $f(x) = x^2$.

2. If you are given the graph of a quadratic with the equation y = $2(x-4)^2 + 2$, what are the coordinates of the vertex? And, is the vertex a maximum or minimum? How do you know?

**Lesson 4 Overview** Lesson 4 of the curriculum plan will be an application of quadratic functions. Students will be introduced to word problems about the path of an object in motion where they will use their knowledge of quadratic functions to answer questions. Students will engage in an online interactive lesson to answer the do now and guided questions and they will end off by completing an exit ticket with a partner.

**How will the lesson engage students using the 5E model?**

| | |
|---|---|
| Engage | Students will engage with interactive materials to identify key features of a quadratic function. Students will complete the do now through quizizz, the notes will be displayed through quizizz as well. |
| Explore | Students will explore the graph of an object in motion by being asked to graph it in their calculator. The do now then asks students to explore the features of this graph by using their knowledge of quadratic function vocabulary. |
| Explain | Students will explain the features of the quadratic function in the do now activity. Students will also have an opportunity to explain their descriptions to the class during a class discussion. Students will use new vocabulary learned about quadratics in their explanations. |
| Elaborate | Students will elaborate on their understanding of the quadratic vocabulary words by completing the quizizz guided questions throughout the lesson. This will further develop their mathematical literacy in regards to quadratic functions. They must be able to understand the terms to answer the questions about the graphs. |
| Evaluate | Students will evaluate their understanding of the lesson by completing the exit ticket. They will be asked to switch papers with a partner and then evaluate the function their partner created. The exit ticket instructions are on the last slide of the quizizz activity. |

**Lesson Plan**

| | |
|---|---|
| Course: | Algebra I |
| Lesson Title/Topic: | Quadratic Function Applications |

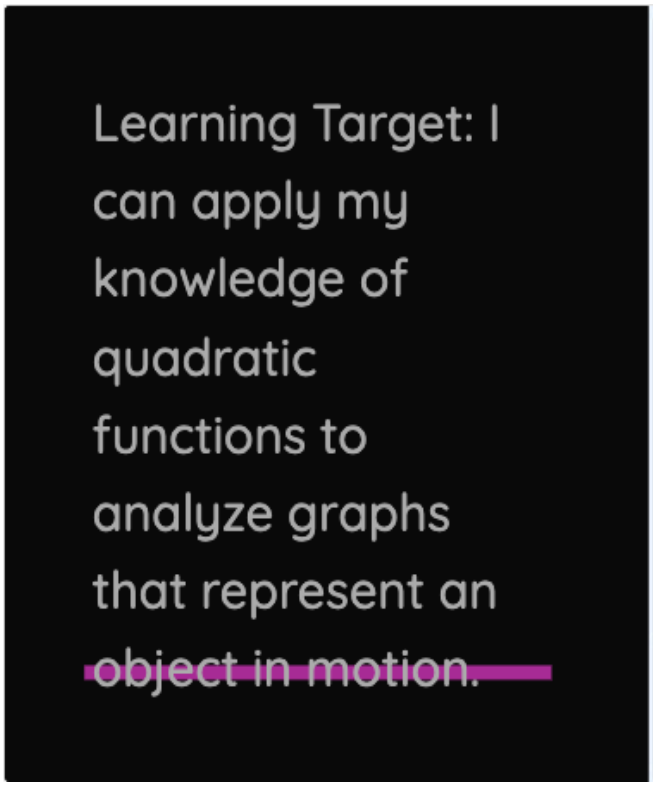
| | |
|---|---|
| Standard(s) Addressed: | AI-F.IF.4. For a function that models a relationship between two quantities: i) interpret key features of graphs and tables in terms of the quantities; and ii) sketch graphs showing key features given a verbal description of the relationship. |
| Learning Target(s) | I can apply my knowledge of quadratic functions to analyze graphs that represent an object in motion. |
| Explore/Warm-up | Students will be asked to join an interactive lesson on quizizz.com using a provided code. When they log on, students will be asked to graph a function in their calculator and "Describe the appearance of the quadratic function with as many vocabulary words as possible (concavity, vertex, maximum, minimum, intercepts)". By using quizizz, this allows me to quickly assess all students' answers. Students are engaged through quizizz, reviewing their knowledge of quadratic function vocabulary and are also expected to explain their responses. After students submit their answers on quizizz, we will have a class discussion where students will explain their responses. |
| Mini-Lesson | The class discussion will bring us to the mini lesson of the day. Students will be introduced to how key vocabulary can be applied to the path of an object in motion. Students will also receive an individual anchor chart of the notes for them to reference throughout the lesson.<br>After going over the anchor chart, students will then need to be taught how to change the bounds on their graphing calculator to make their graph look just like the picture on quizizz. They will change the y-scale and the x-scale on their window of the calculator. |
| Activity/Practice: | After showing students how to change their scale, students will then answer the questions on slides 6-15 of the quizizz lesson. I can assess the students' responses as they answer and help students as needed. |
| Closure: | Students will complete the exit ticket that is displayed on the last slide of the quizizz. They will create an equation that can be graphed to |

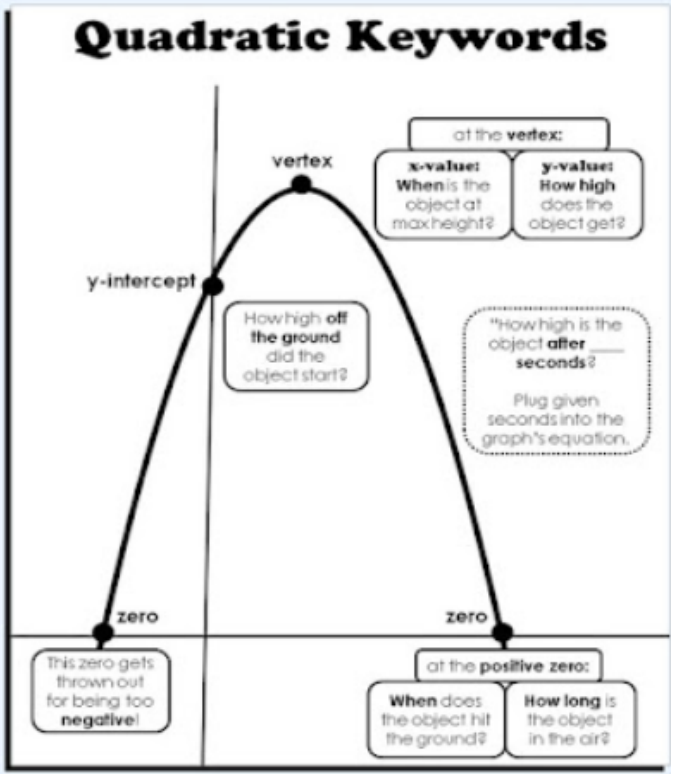
| | |
|---|---|
| | represent the path of an object in motion. They will share with a partner and their partner will answer questions based on the graph. |
| Assessment: | Students will be assessed through their responses on the do now, the interactive lesson questions as well as the exit ticket.<br>Students will also be assessed informally through their responses to my questions throughout the lesson. |
| Resources: | Graphing calculator, quizizz lesson, 1:1 device for students. |

**Lesson 4 Materials**

Quizizz Lesson:

https://quizizz.com/admin/presentation/644d4fcba0353e001dbb3cc7?source=lesson_share

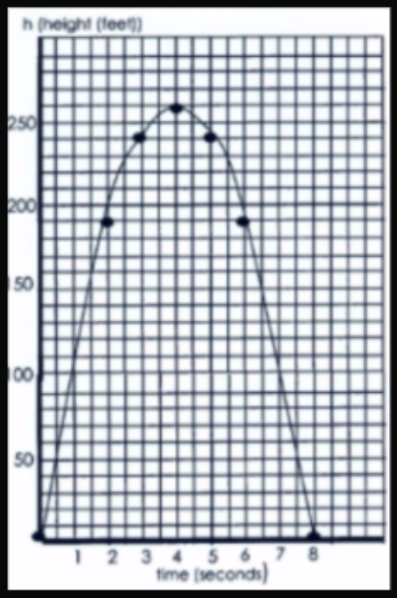



## Do Now:

The graph shows the height "h" in feet of a small rocket "t" seconds after it is launched. The path of the rocket is given by the equation:

$$h(t) = -16t^2 + 128t$$

Graph the function on your calculator and then answer the question on the following slides.

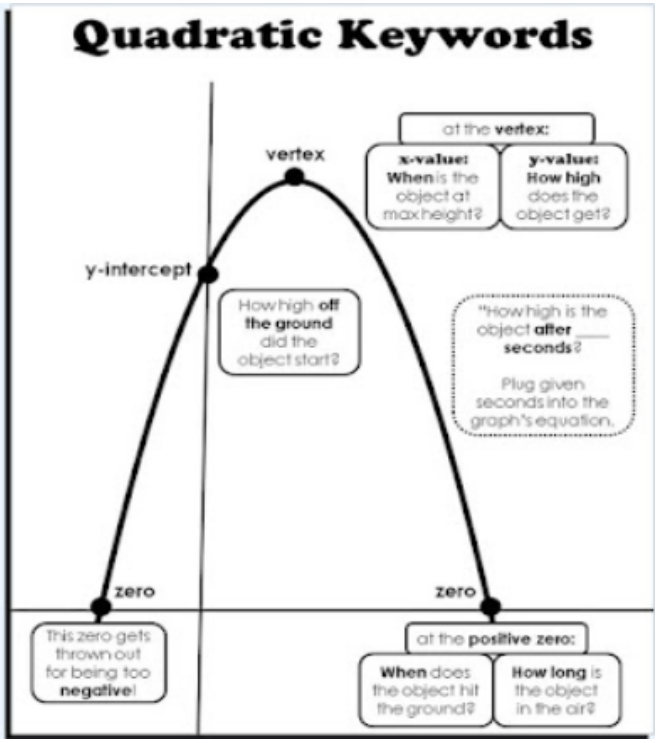



4. Open-ended

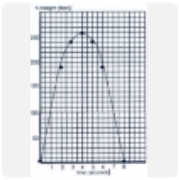
5 minutes | 1 point

Do Now: Describe the appearance of the quadratic function with as many vocabulary words as possible (concavity, vertex, maximum, minimum, intercepts)

Now let's analyze the path of the rocket! But first, you need to zoom in on your calculator. Let's change the bounds!



**6. Multiple-choice** — 3 minutes — 1 point

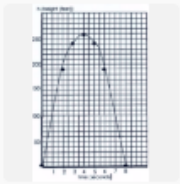


How long is the rocket in the air?

answer choices

- 8 seconds
- 4 seconds
- 6 seconds
- 260 seconds

**7. Multiple-choice** — 3 minutes — 1 point

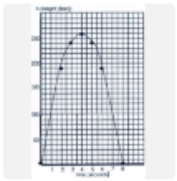


What is the greatest height the rocket reaches?

answer choices

- 250 feet
- 240 feet
- 260 feet
- 260 seconds

**8. Multiple-choice** — 3 minutes — 1 point

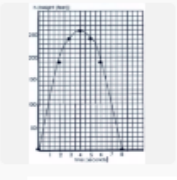


About how high is the rocket after 1 second?

answer choices

- 50 feet
- 100 feet
- 190 feet
- 1 foot

**9. Multiple-choice** — 3 minutes — 1 point

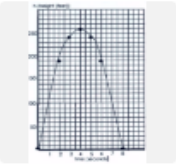


About how high is the rocket after 2 seconds?

answer choices

- 50 feet
- 100 feet
- 190 feet
- 200 feet

**10. Multiple-choice** — 3 minutes — 1 point

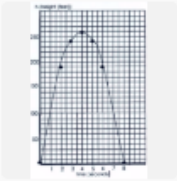


At 2 seconds is the rocket going up or down?

answer choices

- up
- down

**11. Multiple-choice** — 3 minutes — 1 point

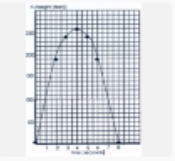


About how high is the rocket after 6 seconds?

answer choices

- 50 feet
- 100 feet
- 190 feet
- 1 foot

**12. Multiple-choice** — 3 minutes — 1 point

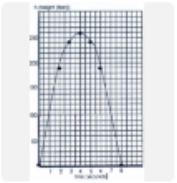


At 6 seconds is the rocket going up or down?

answer choices

- up
- down

**13. Multiple-choice** — 3 minutes — 1 point

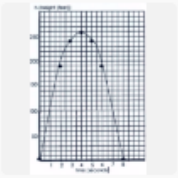


Is the rocket traveling faster between 0-1 second or between 3-4 seconds?

answer choices

- 0-1 second
- 3-4 seconds

**14. Multiple-choice** — 3 minutes — 1 point



Use the equation to find the EXACT value of the height of the rocket at 2 seconds.

$h(t) = -16t^2 + 128t$

answer choices

- 191 feet
- 192 feet
- 193 feet
- 194 feet

**15. Multiple-choice** — 3 minutes — 1 point


This graph represents a DIFFERENT rocket. Use the equation to find the MAXIMUM height of this rocket $f(x) = -16x^2 + 80x$

answer choices

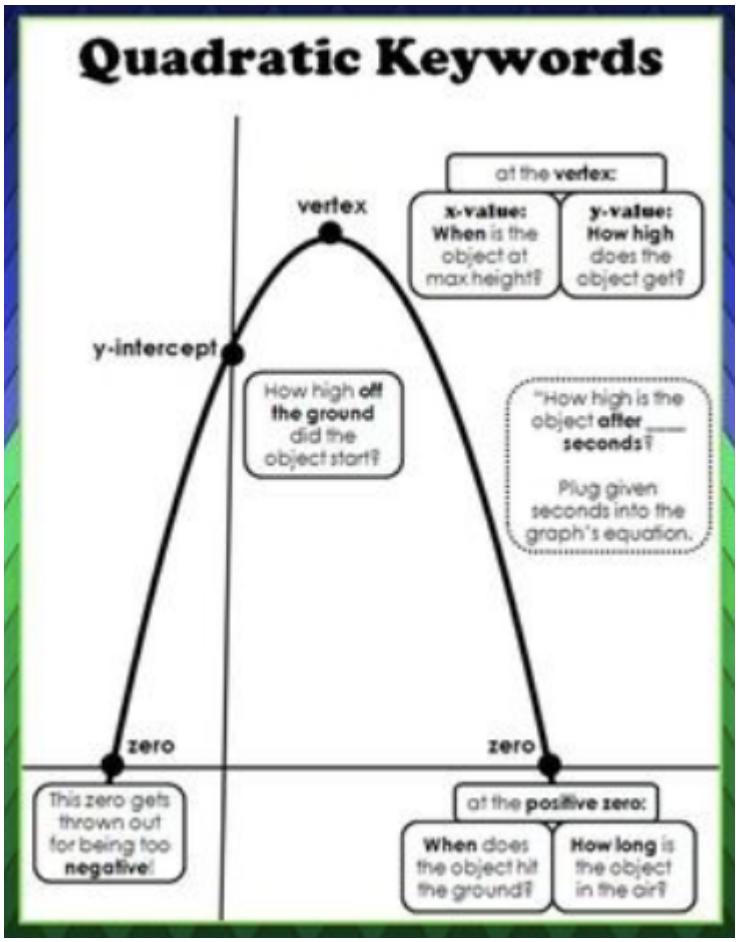
- 200 feet
- 100 feet
- 150 feet
- 50 feet

## Exit Ticket:

**On a piece of paper, create an equation that models the path of an object being thrown. Swap papers with a partner and have them answer the following questions about your equation.**

1. What is the maximum height of the object?
2. What is the time that the object reaches its maximum height?
3. When does the object reach the ground again?

Anchor chart for students to reference



## Classroom Implementation

To situate this curriculum into the classroom, a tenured Algebra I and special education teacher was asked to review these lessons and materials. After using the materials in her classroom, I was provided feedback on how the materials worked in her classroom regarding engagement, scaffolding, and the use of technology.

### Engagement

Working with special education students, it is important to keep them engaged at all time to increase their understanding of the material. With that being said, the different activities incorporated kept students engaged. For example, in lesson one of the curriculum students took notes on an interactive notebook created on google slides, and in lesson two students took notes traditionally with a guided worksheet. Then in lesson three students took notes independently through an exploration activity. The use of these different activities keep students engaged throughout the lesson.

### Scaffolding

Keeping in mind the diverse needs of students with disabilities, certain scaffolds used in this curriculum were beneficial. For example, in lesson three students explored the transformations of quadratic functions on their own using the interactive website created on polypad. When implementing this activity in an integrated co-teacher (ICT) classroom setting, it may be helpful to provide scaffolds such as first modeling how to use the activity to the class. In addition to modeling how to complete the notes, students may also need additional support that require working in groups. If students work in heterogeneous groups based on ability level, the higher performing students can help students who do not perform as well. This means the lessons allow for differentiation for students with special needs, which is important.

## Technology

Each lesson incorporated some type of technology whether it be desmos, google slides, quizizz, or polypad. Even the do now components presented on desmos rather than on paper increased interactivity, participation, and engagement. By incorporating desmos, every student was required to participate in the lesson and answer questions rather than students doing mental mathematics. This helped with differentiation since some students were not comfortable answering questions in front of the class.

In conclusion, the lessons in this curriculum were found to be engaging and allowed scaffolding and the incorporation of technology. The special education mathematics teacher feedback reveals the lessons were easily differentiable to meet student learning needs. It is my hope that other teachers can also use these materials in their classrooms and that they are found to be easily modified as needed to support student learning.

## Conclusion

The goal of this curriculum is to provide mathematics teachers with an example of how student-centered instruction can be used in a mathematics classroom through the 5E instructional model. This curriculum provides four lessons that allows students to be actively engaged in their own learning while also using instructional technology to enhance the instruction. The answer keys for all lesson materials can be found in the appendix. As the author of this curriculum project, it is my hope that mathematics teachers use this curriculum in their own classrooms to help them shift to a more student-centered learning approach to instruction so that student engagement is increase

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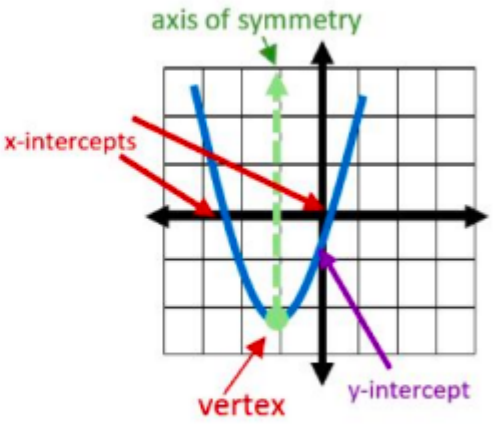
## Appendix

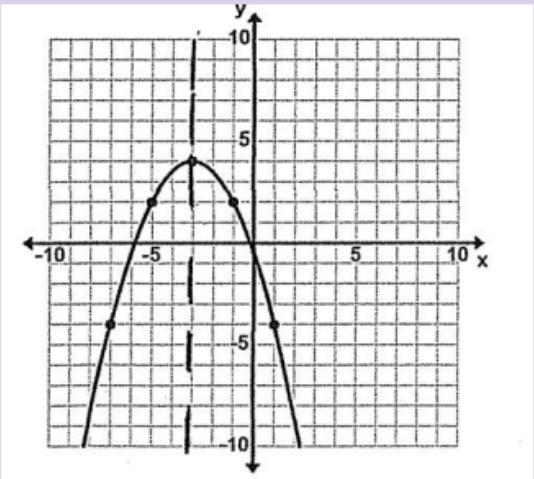
Lesson 1 Interactive Notebook Slides

**Key Vocabulary:**

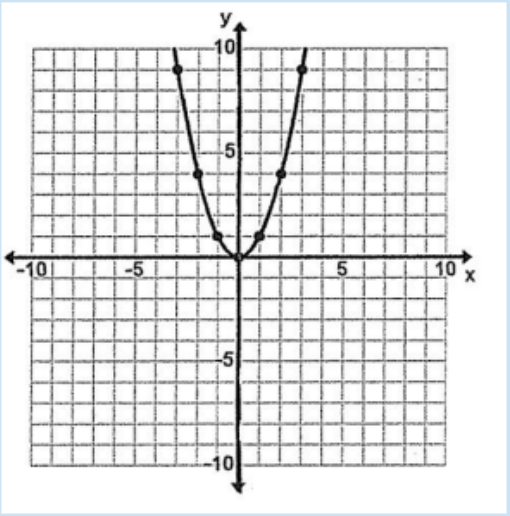
- A function where the highest exponent is squared is called a QUADRATIC function.
- The graph of a quadratic function is a U shaped curve called a PARABOLA.
- The highest or lowest point of the graph is called the VERTEX. It can also be considered the TURNING POINT.



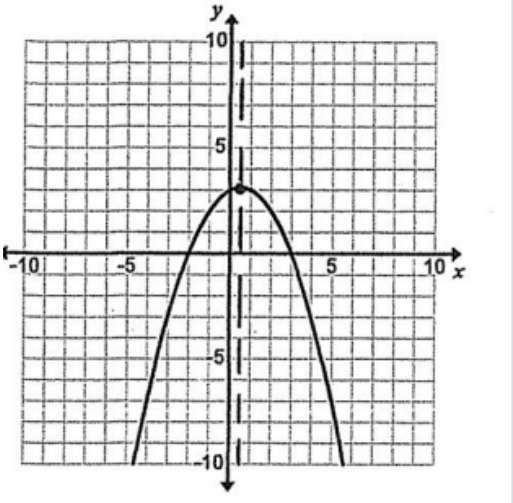

- The AXIS OF SYMMETRY is the vertical line that passes through the vertex and divides the graph into two mirror images.
- The x-values where the graph crosses the x-axis are called the X-INTERCEPTS or the ROOTS.
- The point where the graph crosses the y-axis is called the Y-INTERCEPTS.




1. **Vertex:** (-3, 4)
2. **Roots/x-intercepts:** (-6, 0) and (0,0)
3. **Max or Min?** Minimum
4. **Axis of Symmetry:** x = -3
5. **Y-intercept:** (0,0)




1. **Vertex:** (0,0)
2. **Roots/x-intercepts:** (0,0)
3. **Max or Min?** Minimum
4. **Axis of Symmetry:** x = 0
5. **Y-intercept:** (0,0)

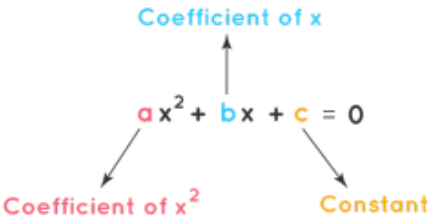



1. **Vertex:** (0.5, 3)
2. **Roots/x-intercepts:** (-2, 0) and (3, 0)
3. **Max or Min?** Maximum
4. **Axis of Symmetry:** x = 0.5
5. **Y-intercept:** (0, 3)

Name: Answer Key Date: Period:

Learning Target: I can graph a quadratic function in standard form.

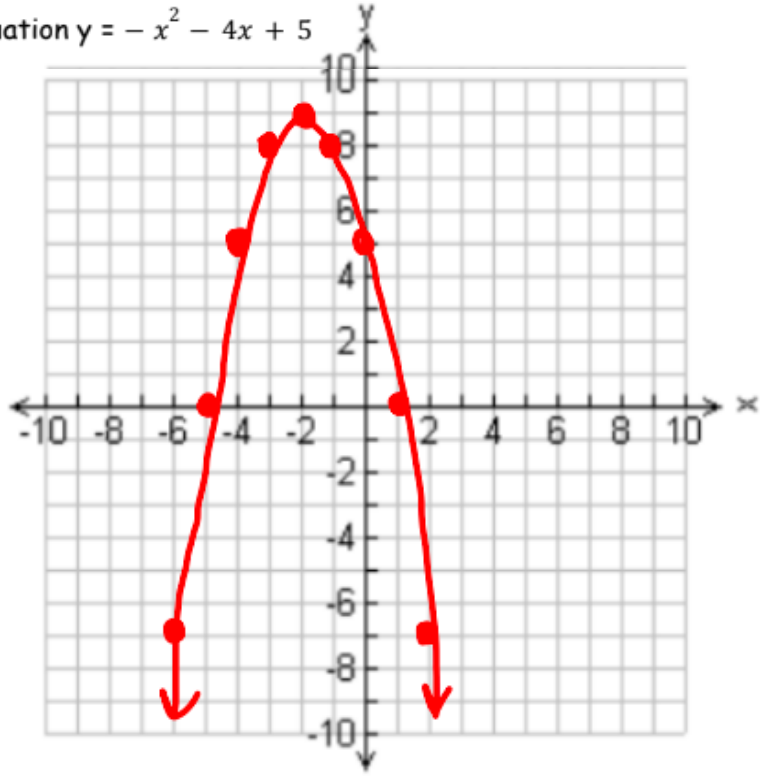
Standard Form of a Quadratic Equation




Steps to graphing a Quadratic Equation:

1. Type the equation into y = on your graphing calculator
2. Look at the table and identify the VERTEX.
3. Copy down the table of values centered around the vertex.
4. Plot all points that fit on the graph and connect with a curved U.
5. 
6. Example #1: Graph the equation $y = -x^2 - 4x + 5$

| x | y |
|---|---|
| -6 | -7 |
| -5 | 0 |
| -4 | 5 |
| -3 | 8 |
| -2 | 9 |
| -1 | 8 |
| 0 | 5 |
| 1 | 0 |
| 2 | -7 |



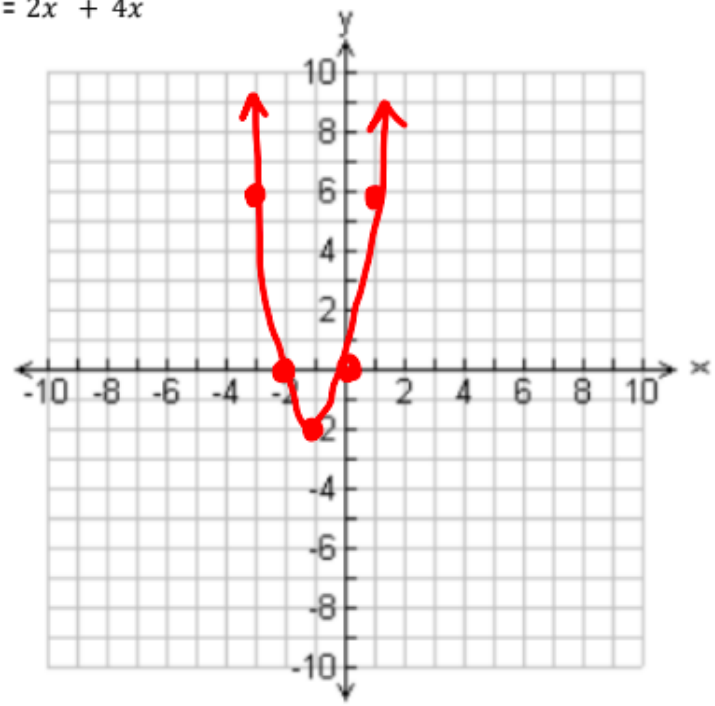

Vertex: (-2,9)

Axis of Symmetry: X = -2

Roots: X = {-5, 1}

Example #2: Graph the equation $y = 2x^2 + 4x$

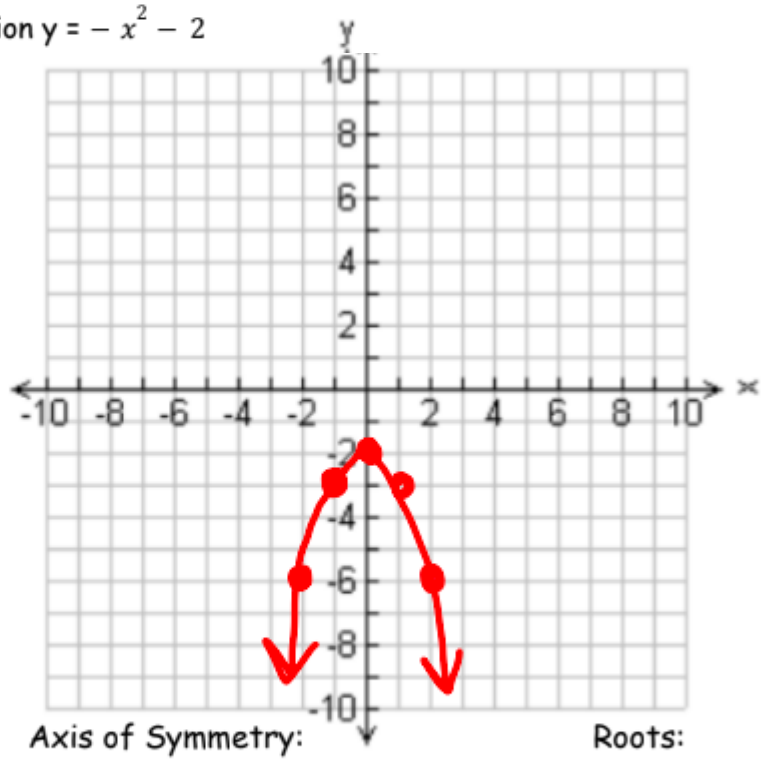
| x | y |
|---|---|
| -3 | 6 |
| -2 | 0 |
| -1 | -2 |
| 0 | 0 |
| 1 | 6 |




Vertex: $(-1,-2)$ Axis of Symmetry: $x = -1$ Roots: $x = \{-2, 0\}$

Example #3: Graph the equation $y = -x^2 - 2$

| x | y |
|---|---|
| -3 | -11 |
| -2 | -6 |
| -1 | -3 |
| 0 | -2 |
| 1 | -3 |
| 2 | -6 |
| 3 | -11 |



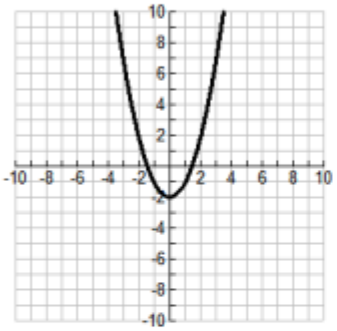

Vertex: $(0,-2)$ Axis of Symmetry: $x = 0$ Roots: None

Lesson 2 Relay Activity

# Answer Key for Teacher

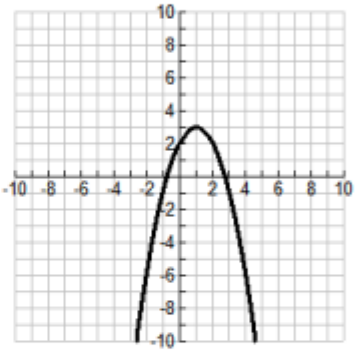
## *Relay Activity: Graph Quadratics in Standard Form*

1. $y = x^2 - 2$



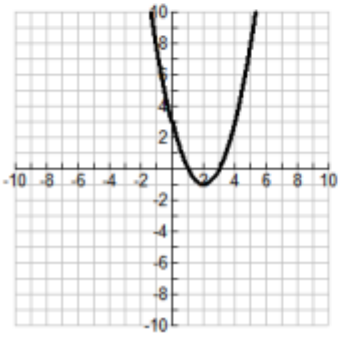
| x | f(x) |
|---|---|
| -2 | 2 |
| -1 | -1 |
| 0 | -2 |
| 1 | -1 |
| 2 | 2 |

2. $f(x) = -x^2 + 2x + 2$



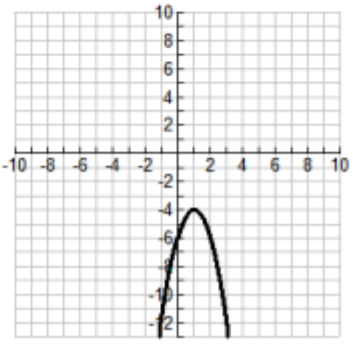
| x | f(x) |
|---|---|
| -1 | -1 |
| 0 | 2 |
| 1 | 3 |
| 2 | 2 |
| 3 | -1 |

3. $f(x) = x^2 - 4x + 3$



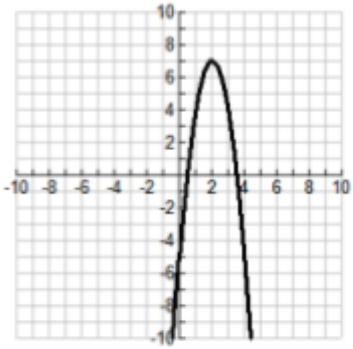
| x | f(x) |
|---|---|
| 0 | 3 |
| 1 | 0 |
| 2 | -1 |
| 3 | 0 |
| 4 | 3 |

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



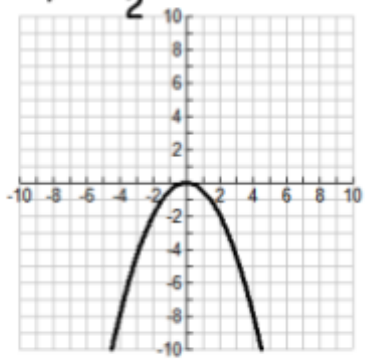
| x | f(x) |
|---|---|
| -1 | -12 |
| 0 | -6 |
| 1 | -4 |
| 2 | -6 |
| 3 | -12 |

5. $f(x) = -3x^2 + 12x - 5$



| x | f(x) |
|---|---|
| 0 | -5 |
| 1 | 4 |
| 2 | 7 |
| 3 | 4 |
| 4 | -5 |

6. $y = -\frac{1}{2}x^2$



| x | f(x) |
|---|---|
| -4 | -8 |
| -3 | -4.5 |
| -2 | -2 |
| -1 | -0.5 |
| 0 | 0 |
| 1 | -0.5 |
| 2 | -2 |
| 3 | -4.5 |
| 4 | -8 |

Name: Answer Key Date: Period:

Learning Target: I can describe how the constants a, h and k affect the graph of the quadratic function $g(x) = a(x - h)^2 + k$.

**Polypad:** https://mathigon.org/polypad/ad6MHfeyZhUSw

**Warm-up:** On the polypad you have the graph of a parent quadratic function shown on the coordinate plane. Please answer the following questions about the graph.

a. What are the coordinates of the vertex? (0,0)

b. Does the graph have a maximum or minimum? minimum

c. What is the equation of the axis of symmetry? x = 0

d. What are the roots of the graph? x = 0

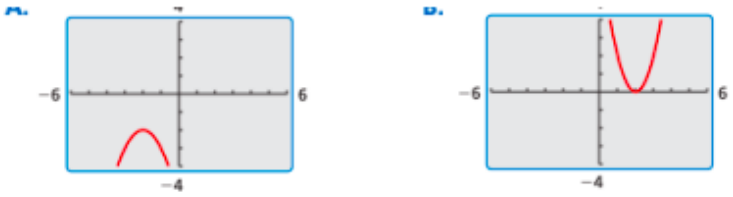
---

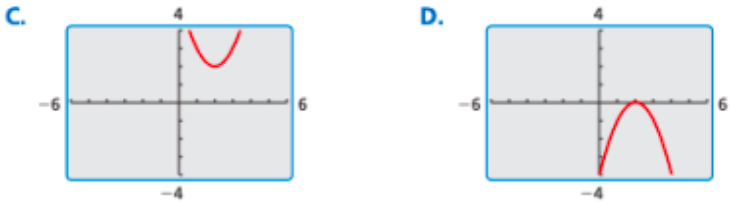
**Exploration:** Using the polypad that was shared with you, play around the with values of a, h, and k, to match the following quadratic equations with their graphs. Explain your reasoning using evidence from the polypad.

**a.** $g(x) = -(x - 2)^2$ **b.** $g(x) = (x - 2)^2 + 2$ **c.** $g(x) = -(x + 2)^2 - 2$

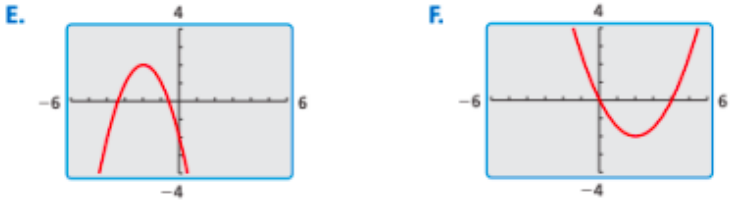
**d.** $g(x) = 0.5(x - 2)^2 - 2$ **e.** $g(x) = 2(x - 2)^2$ **f.** $g(x) = -(x + 2)^2 + 2$

c




f



| | |
|---|---|
| A: c) $g(x) = -(x+2)^2 - 2$ | B: e) $g(x) = 2(x-2)^2$ |
| C: b) $g(x) = (x-2)^2 + 2$ | D: a) $g(x) = -(x-2)^2$ |
| E: f) $g(x) = (x+2)^2 + 2$ | F: d) $g(x) = .5(x-2)^2 - 2$ |

**Guided Questions:**

Part I: How does "**a**" affect the graph of the quadratic?

- What was the visual effect when you changed the value of a?

  wider or skinnier
- What happened when a was negative?

  concave down
- What happened when a was positive?

  concave up
- What did the graph look like when a > 1 versus 0 < a < 1 ?

  a>1, wider
- Did the vertex change?

  NO

Part II: How does "h" affect the graph of the quadratic?

- What was the visual effect when you changed the value of h?

  left or right shifts
- What happened when h was negative?

  right
- What happened when h was positive?

  left

- Did the vertex change?

yes

Part III: How does "k" affect the graph of the quadratic?

- What was the visual effect when you changed the value of k?

Up or down shift

- What happened when k was negative?

down

- What happened when k was positive?

up

- Did the vertex change?

yes

**Conclusion:**

1. In a brief summary please sum up how a, h and k, transform the graph of $f(x) = x^2$.

a: widens/shrinks
h: vertical shift
k: horizontal shift

2. If you are given the graph of a quadratic with the equation $y = 2(x - 4)^2 + 2$, what are the coordinates of the vertex? And, is the vertex a maximum or minimum? How do you know?

Vertex: (4, 2)
& Minimum