Performance Based Learning and Assessment Task

Discovering Quadratics

I. **ASSESSSMENT TASK OVERVIEW & PURPOSE:**
The students are instructed to determine the optimal length of time to maximize the "good" kernels of popped popcorn in the microwave.

II. **UNIT AUTHOR:**
Leslie Cumbow, Abingdon High School, Washington County Schools

III. **COURSE:**
Algebra II

IV. **CONTENT STRAND:**
Algebra II – Functions, Statistics

V. **OBJECTIVES:**
- The student will investigate and analyze functions algebraically and graphically.
- The student will recognize the general shape of function (absolute value, square root, cube root, rational, polynomial, exponential, and logarithmic) families and will convert between graphic and symbolic forms of functions. A transformational approach to graphing will be employed. Graphing calculators will be used as a tool to investigate the shapes and behaviors of these functions.
- The student will investigate and describe the relationships among solutions of an equation, zeros of a function, *x*-intercepts of a graph, and factors of a polynomial expression.
- The student will collect and analyze data, determine the equation of the curve of best fit, make predictions, and solve real-world problems, using mathematical models. Mathematical models will include polynomial, exponential, and logarithmic functions.

VI. **REFERENCE/RESOURCE MATERIALS:**
Calculator, Graph paper, Compute access, microwave popcorn (different brand for each group), microwave (at home)

VII. **PRIMARY ASSESSMENT STRATEGIES:**
Students will be assessed on how appropriately their data fits the equation. Students will also be assessed on the quality of their marketing presentation. Students will be assessed on how adequately they explain their results.

VIII. **EVALUATION CRITERIA:**
- A rubric will be used to include the main points of the discussion.
- Determine if functions have been determined correctly.
- Check to see if the line of best fit has been calculated correctly
- Check the graph of time vs. good kernels and good kernels vs. total kernels

IX. **INSTRUCTIONAL TIME:**
The first activity will take approximately two 90 minutes blocks to complete. The second will take one 90 minute block.

Activity 1: Pop Goes the Corn

Strand

Algebra II – Functions/Statistics

Related SOL

AII.6 The student will recognize the general shape of function (absolute value, square root, cube root, rational, polynomial, exponential, and logarithmic) families and will convert between graphic and symbolic forms of functions. A transformational approach to graphing will be employed. Graphing calculators will be used as a tool to investigate the shapes and behaviors of these functions.

AII.8 The student will investigate and describe the relationships among solutions of an equation, zeros of a function, *x*-intercepts of a graph, and factors of a polynomial expression.

AII.7 The student will investigate and analyze functions algebraically and graphically.

AII.9 The student will collect and analyze data, determine the equation of the curve of best fit, make predictions, and solve real-world problems, using mathematical models. Mathematical models will include polynomial, exponential, and logarithmic functions.

NCTM Standards:

- for bivariate measurement data, be able to display a scatterplot, describe its shape, and determine regression coefficients, regression equations, and correlation coefficients using technological tools;
- recognize how linear transformations of univariate data affect shape, center, and spread;

Materials/Resources

- Graphing calculators
- Graph paper
- Microwave
- Several bags of popcorn (each group needs a different brand)
- Worksheet
- Homework
- Posterboard materials

Assumption of Prior Knowledge

- Students should have a basic knowledge of quadratic functions.
- Students should understand how to plot points on the coordinate plane.
- Students should understand how to input the data into a graphing calculator and use the calculator to determine the curve of best fit.

- Students should know how to use the curve of best fit to make predictions.

Introduction: Setting Up the Mathematical Task

In this activity, you will investigate the relationship between the amount of time you microwave a bag of popcorn and how many "good" kernels it produces. A "good" kernel is defined as one that is fully popped and has no burnt places. You will then use this data to make a curve of best fit for your particular brand of popcorn.

Activity 1: Popcorn Data Collection

1. Divide into groups of 3-4
2. The teacher will assign your group a brand of popcorn and issue you 8 unpopped bags.
3. Your group will pop the popcorn in the microwave (at home) using various lengths of time given in the table.
4. After you have popped the bag, you will count the number of "good" kernels (fully popped with no burnt places) and the total kernels for each bag.
5. You will put your collected data into a table of time versus good kernels and another table of good kernels versus total kernels.
6. Graph both sets of data on the graph paper and determine what type of function you have for each.
7. Using the graphing calculator, find the curve of best fit for each table for your brand.
8. Determine the optimal time you should pop your brand to maximize the amount of good kernels.
9. Use the equations to make predictions about how many kernels other times would produce and how many total kernels you would have based on how many good kernels you had.
10. Design a poster for a marketing campaign based on your findings and present to the class.

Student Exploration:

- **Individual Work** – The individual student will make a conjecture of how they think the graph of the time versus "good" kernels would appear. The student must have a basic knowledge before entering small group work.
- **Small Group Work -** The students will pop their 8 bags of popcorn for 8 different lengths of time and count how many "good" kernels they had in each bag. They will then note the data in the form of a table and enter it into the graphing calculator. Once the data is entered, they should determine the equation for the curve of best fit. After they find the

equation for the curve of best fit, they will use it to find the optimal amount of time they should pop their brand of corn to maximize the amount of "good" kernels. Your group will then make a marketing poster for your product to share the results with the class.

- **Whole Class Sharing/Discussion** – The small groups will then come back together to present their findings to the class.

Student/Teacher Actions:

- **What should students be doing?** The students should be following the directions above within their small groups.
- **What should teachers be doing to facilitate learning?** Teachers should be constantly monitoring the groups to ensure they are using the correct processes on the calculator. They should also be available for methodical questions but not hints on the type of function. If students are having trouble, they can use the textbook, internet, or classmates for help.
- **Possible questions** – Possible problems the students may face are those dealing with what type of function the two graphs create and what the relationship is between them. Once the students choose the correct function and find the curve of best fit, they should be able to discover the correct equation quickly.
- **Technology Integration or Cooperative/Collaborative Learning Possibilities** – Students will be using the graphing calculator to produce the curve of best fit.

Monitoring Student Responses

- Students will communicate with their peers in a group discussion why they chose the function.
- Students will record those chosen equations that work and also those that will not work and why.
- Teacher will also extend extra instruction to those struggling and will also re-shuffle the groups so that different ideas can be spread by different students into different groups.

- Summary
  - Students will design a marketing poster of their findings to sell their brand of popcorn and present the findings to the class.
  - Students will turn in group work tables and poster and individual paragraphs to document their work.

Assessment List and Benchmarks

<u>Assessment List for Activity: Pop goes the Corn</u>

			Earned Assessment	
Num	**Element**	**Point Value**	**Self**	**Teacher**
1	Corn is popped for 10 different lengths of time and data recorded.	2		
2	Total good kernels and total kernels for each bag are recorded.	2		
3	Tables are correctly labeled and data is entered into the calculator.	2		
4	A graph is drawn for the time vs. good kernels	2		
5	An equation is generated for the time vs. good kernels relationship.	2		
6	A graph is drawn for the good kernels vs. total kernels	2		
7	An equation is generated for the good kernels vs. total kernels	2		
8	Predictions are made based on the equations.	2		
9	Written conclusion is turned in with group work.	4		
10	Poster and presentation are completed.	10		
	Total	30		

RUBRIC FOR ACTIVITY				
#	**Element**	**0**	**1**	**2**
1	Corn is popped for 10 different lengths of time and data recorded.	No popped bags	Only some bags were popped	All bags were popped
2	Total good kernels and total kernels for each bag are recorded.	No data recorded	Some data recorded	All data recorded
3	Tables are correctly labeled and data is entered into the calculator.	No tables labeled or entered	Some tables labeled and entered	All tables labeled and entered
4	A graph is drawn for the time vs. good kernels	No graph drawn	Graph drawn but not accurately	Accurate graph drawn reflecting data from table.
5	An equation is generated for the time vs. good kernels relationship.	No equation	Equation generated but does not fit data	Correct equation generated
6	A graph is drawn for the good kernels vs. total kernels	No graph drawn	Graph drawn but not accurately	Accurate graph drawn reflecting data from table.
7	An equation is generated for the good kernels vs. total kernels	No equation	Equation generated but does not fit data	Correct equation generated
8	Predictions are made based on the equations.	No predictions made	Predictions made but not entirely correct	Predictions made correctly
9	Written conclusion is turned in with group work.	No written conclusion	Written conclusion turned in but does not discuss all findings(2)	Written conclusion submitted with all the points of the activity discussed.(4)
10	Poster and presentation are completed.	No poster or presentation	Poster and presentation done but do not include all findings(5)	Poster and presentation completed with all findings included.(10)

Benchmarks

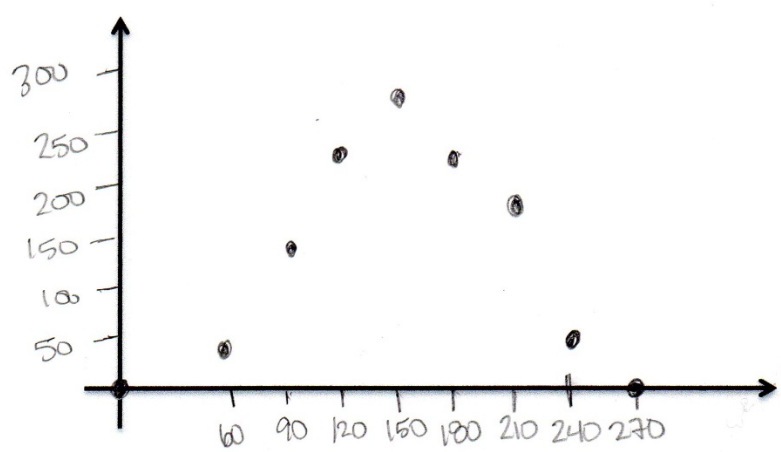
Group Members Key

Popcorn Brand Boy Scout

Bag number	Time	Good Kernels
	0 seconds	0
1	60 seconds	42
2	90 seconds	144
3	120 seconds	217
4	150 seconds	282
5	180 seconds	223
6	210 seconds	188
7	240 seconds	28
8	270 seconds	0

Equation for Time vs Good Kernels: $y = -0.01x^2 + 3.78x - 50.30$

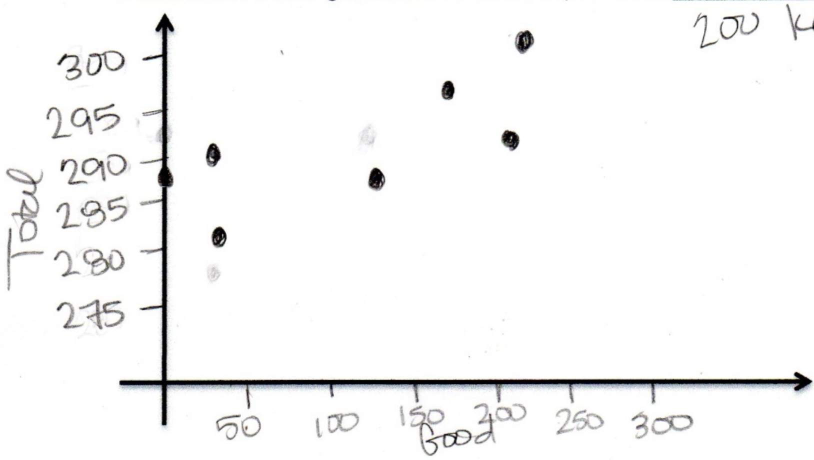
Predictions for 2 other times not in your table: 100 seconds : 228
200 seconds = 306



Bag number	Time	Good Kernels	Total Kernels
1	60 seconds	42	281
2	90 seconds	144	287
3	120 seconds	217	290
4	150 seconds	282	294
5	180 seconds	223	301
6	210 seconds	188	295
7	240 seconds	28	290
8	270 seconds	0	287

Equation for Good vs Total: $y = 0.04x + 285.14$

Predictions for 2 other good kernel values not in your table: 100 kernels: 289 total
200 kernels: 293 total



What kind of function is each of these? Quadratic and Linear

What would be the appropriate domain for each function? Why?
1st Graph: $0 \le x \le 270$ 2nd: All real numbers, answers vary

What would be the optimal time to pop your brand of popcorn to get the most GOOD kernels?
max: (189, 307) therefore: 189 seconds

What is the relationship between the two graphs?

Answers will vary

Homework

Use the given data to find the curve of best fit in the calculator.

1.) **PUMPKIN TOSSING** A pumpkin tossing contest is held each year in Morton, Illinois, where people compete to see whose catapult will send pumpkins the farthest. One catapult launches pumpkins from 25 feet above the ground at a speed of 125 feet per second. The table shows the horizontal distances (in feet) the pumpkins travel when launched at different angles. Use a graphing calculator to find the best-fitting quadratic model for the data.

Angle (degrees)	20	30	40	50	60	70
Distance (feet)	372	462	509	501	437	323

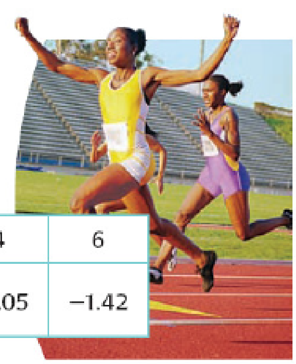
Step 1: Enter the data into two lists of a graphing calculator.

Step 2: Make a scatter plot of the data…watch your window. What do the points look like?

Step 3: Use the quadratic regression feature to find the model for the data.

Step 4: Check how well the model fits the data by graphing the model and the data in the same view screen on your calculator.

2.) **RUNNING** The table shows how wind affects a runner's performance in the 200 meter dash. Positive wind speeds correspond to tailwinds, and negative wind speeds correspond to headwinds. The change t in finishing time is the difference beween the runner's time when the wind speed is s and the runner's time when there is no wind.



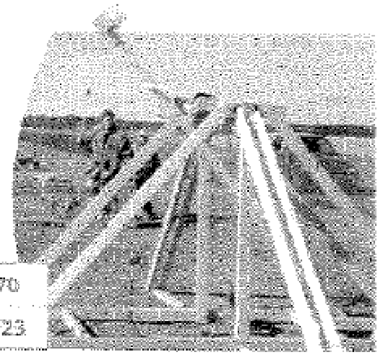
Wind speed (m/sec), s	−6	−4	−2	0	2	4	6
Change in finishing time (sec), t	2.28	1.42	0.67	0	−0.57	−1.05	−1.42

a. Use a graphing calculator to find the best-fitting quadratic model.

b. Predict the change in finishing time when the wind speed is 10 m/sec.

Use the given data to find the curve of best fit in the calculator.

1.) **PUMPKIN TOSSING** A pumpkin tossing contest is held each year in Morton, Illinois, where people compete to see whose catapult will send pumpkins the farthest. One catapult launches pumpkins from 25 feet above the ground at a speed of 125 feet per second. The table shows the horizontal distances (in feet) the pumpkins travel when launched at different angles. Use a graphing calculator to find the best-fitting quadratic model for the data.



Angle (degrees)	20	30	40	50	60	70
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Step 1: Enter the data into two lists of a graphing calculator.

Step 2: Make a scatter plot of the data...watch your window. What do the points look like?

Step 3: Use the quadratic regression feature to find the model for the data.

$y = -0.26x^2 + 22.59x + 23.03$

Step 4: Check how well the model fits the data by graphing the model and the data in the same view screen on your calculator.

$r^2 = 0.99$

2.) **RUNNING** The table shows how wind affects a runner's performance in the 200 meter dash. Positive wind speeds correspond to tailwinds, and negative wind speeds correspond to headwinds. The change t in finishing time is the difference beween the runner's time when the wind speed is s and the runner's time when there is no wind.

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Change in finishing time (sec), t	2.28	1.42	0.67	0	−0.57	−1.05	−1.42

a. Use a graphing calculator to find the best-fitting quadratic model.

b. Predict the change in finishing time when the wind speed is 10 m/sec.

$y = 0.01x^2 - 0.31x - 0.00048$

$y = 0.01(10)^2 - 0.31(10) - 0.00048$

$y = -2.10$

1. Divide into groups of 3-4
2. The teacher will assign your group a brand of popcorn and issue you 8 unpopped bags.
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Group Members____________________
____
____
____

Popcorn Brand ____________________________

Bag number	Time	Good Kernels
1	90 seconds	
2	120 seconds	
3	150 seconds	
4	180 seconds	
5	210 seconds	
6	240 seconds	
7	270 seconds	
8	300 seconds	

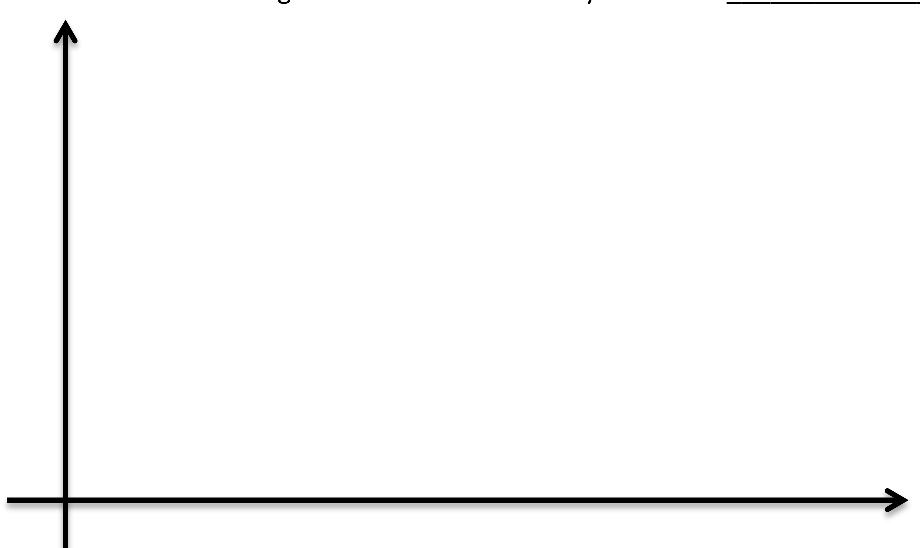
Equation for Time vs Good Kernels: __________________________

Predictions for 2 other times not in your table: ________________________________

Bag number	Time	Good Kernels	Total Kernels
1	90 seconds		
2	120 seconds		
3	150 seconds		
4	180 seconds		
5	210 seconds		
6	240 seconds		
7	270 seconds		
8	300 seconds		

Equation for Good vs Total: ___________________________

Predictions for 2 other good kernel values not in your table: _________________________________



What kind of function is each of these?

How do you know that it fits this family of functions?

What evidence do you have to support your decision for this family of functions (relationship between the data, graphical representations, etc)?

What would be the appropriate domain for each function? What does domain represent in each function, in context of the question?

What would be the optimal time to pop your brand of popcorn to get the most GOOD kernels? How did you figure this out? What is this value graphically?

What is the relationship between the two graphs?

Activity 2: The Real Quadratics of the United States

Strand

Algebra II – Functions/Statistics

Related SOL

AII.6 The student will recognize the general shape of function (absolute value, square root, cube root, rational, polynomial, exponential, and logarithmic) families and will convert between graphic and symbolic forms of functions. A transformational approach to graphing will be employed. Graphing calculators will be used as a tool to investigate the shapes and behaviors of these functions.

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NCTM Standards:

- for bivariate measurement data, be able to display a scatterplot, describe its shape, and determine regression coefficients, regression equations, and correlation coefficients using technological tools;
- recognize how linear transformations of univariate data affect shape, center, and spread;

Materials/Resources

- Graphing calculators
- Graph paper
- Computer
- Geogebra
- Picture of a Quadratic
- Activity sheet
- Homework

Assumption of Prior Knowledge

- Students should have a basic knowledge of quadratic functions including vertex form of a quadratic equation and identifying the components of a parabola in the graph.
- Students should understand how to plot points on the coordinate plane.

- Students should understand how to input the data into a graphing calculator and use the calculator to determine the curve of best fit.
- Students should know how to use the curve of best fit to make predictions.
- Working knowledge of Geogebra software.

Introduction: Setting Up the Mathematical Task

In this activity, the students will find pictures of parabolic curves in the real world using the internet. The students will save these pictures and paste them into Geogebra to find the vertex. They will also need to research the actual dimensions of the object so they can adjust the scale of their axis. *Suggestions to offer students: McDonald's sign, bridge, water fountain, hose*

<u>Activity 2: The Real Quadratics of the United States</u>

1. Find an example of a real world parabolic curve and its dimensions. (You cannot use the Gateway Arch! Can be structural, manmade, or formed by you)
2. Open Geogebra and insert the picture into the file. Include the axis and adjust the scale to correspond to the actual size.
2. Insert a point for the vertex of your picture.
3. Find an additional point that your graph passes through.
4. Calculate the equation in vertex form for the curve using the vertex and the point.
5. Expand your equation into standard form and then pair up. Each partner gives their standard form equation to the other and then attempts to calculate the vertex of their partner's parabola.
6. Perform the requested transformations on each.
7. Be prepared to discuss your findings with the group.

Student Exploration:

- **Individual Work** – Each student should have a picture of a quadratic they can save to the computer. They will then work individually on finding the equation for their quadratic.
- **Small Group Work -** The students will work with a partner and attempt to determine the other person's vertex from the standard form.
- **Whole Class Sharing/Discussion** – The small groups will then come back together to present talk about their findings as a class.

Student/Teacher Actions:

- **What should students be doing?** The students should be following the directions above individually and within their small groups.
- **What should teachers be doing to facilitate learning?** Teachers should be constantly monitoring the groups to ensure they are using the correct processes on the computer. They should also be available for methodical questions but not hints on the equation for the function. If students are having trouble, they can use the textbook, internet, or classmates for help.
- **Possible questions** – Possible problems the students may face are those dealing with how to use the software to find points and how to calculate the equation of the function.
- **Technology Integration or Cooperative/Collaborative Learning Possibilities** – Students will be using Geogebra software to determine points of their quadratic function.

Monitoring Student Responses

- Students will communicate with their peers in a group discussion why they chose the function.
- Students will record those chosen points that work and also those that will not work and why.
- Teacher will also extend extra instruction to those struggling and will also re-shuffle the groups so that different ideas can be spread by different students into different groups.

- Summary
    - Students will turn in a copy of their picture with the axis and the points labeled as well as the equations they determined.
    - Students will analyze the transformations the teacher assigned and explain how it would affect the item pictured.

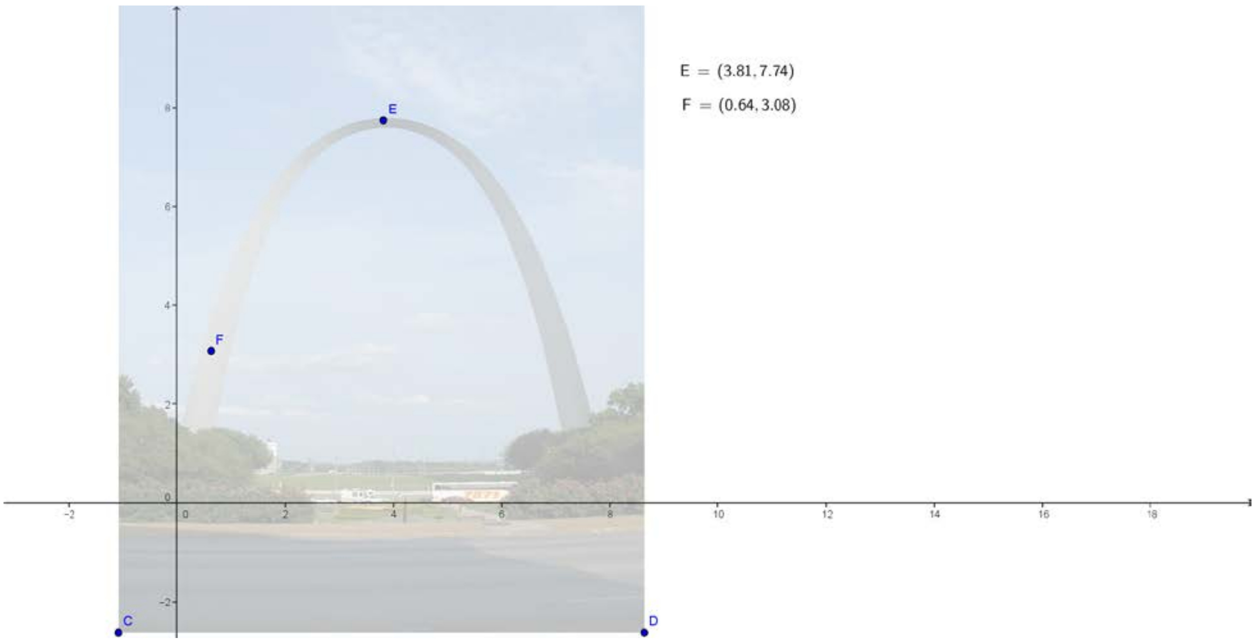
Assessment List and Benchmarks

Assessment List for Activity: Real Quadratics of the United States

			Earned Assessment	
Num	**Element**	**Point Value**	**Self**	**Teacher**
1	Picture is of a parabola	2		
2	Dimensions of parabola are noted.	2		
3	Picture is inserted into Geogebra correctly	2		
4	Vertex and second point are identified correctly	2		
5	Equation in vertex form is computed correctly	2		
6	Vertex of partner's equation is calculated correctly	2		
7	Transformations are done correctly	2		
8	Worksheet is completed	2		
9	Presentation is made and findings are explained.	2		
	Total	18		

RUBRIC FOR ACTIVITY				
#	**Element**	**0**	**1**	**2**
1	Picture is of a parabola	No picture is turned in	N/A	Picture is of a Parabola
2	Dimensions of parabola are noted.	No dimensions given	Dimensions given incorrectly	
3	Picture is inserted into Geogebra correctly	No picture inserted	N/A	Picture inserted correctly
4	Vertex and second point are identified correctly	Points are not correctly identified	One point is correctly identified	Both points are correctly identitfied
5	Equation in vertex form is computed correctly	No equation is computed	Equation is computed with error	Equation is done correctly
6	Vertex of partner's equation is calculated correctly	Vertex is not found	Vertex is found but incorrect	Correct vertex is found
7	Transformations are done correctly	Transformations are not done	Transformations are done but incorrectly	Transformations are done correctly
8	Worksheet is completed	Worksheet is not completed	Worksheet is completed with error	Worksheet is correctly completed
9	Presentation is made and findings are explained.	Presentation is not made	Presentations is made without all of the information	Presentation is made with complete findings

Benchmarks



Dimensions of the Gateway Arch:

630 feet tall and 630 feet wide

Your graph:

Vertex: (3.81, 7.74)

Point: (0.64, 3.08)

Equation in vertex form: $y = -0.4637(x-3.81)^2 + 7.74$

Your partner's equation in standard form:

Vertex of your partner's equation:

Transformations of your function:

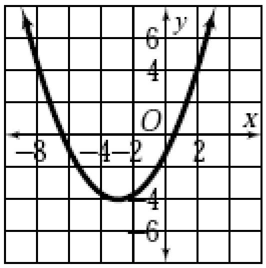
What would happen to the equation if we multiplied the a-value by $\frac{1}{2}$? Changes to -0.23185

How does this affect the item in your picture? the arch would be wider because the absolute value is smaller

If you picked up your parabola and moved it to the left 4 and down 2, how does this affect your equation? $y = -0.4637(x-7.81)^2 + 5.74$

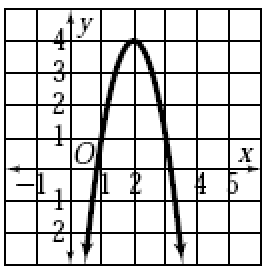
Homework

Use the graph provided to write an equation for a parabola in vertex form and standard form.

1) 

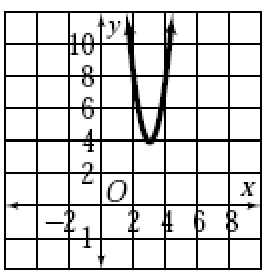
Vertex: ___________________

Standard: _________________

2) 

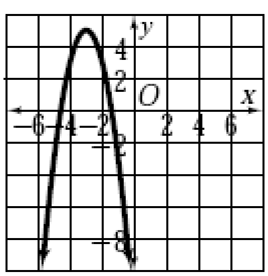
Vertex: ___________________

Standard: _________________

3) 

Vertex: ___________________

Standard: _________________

4) 

Vertex: ___________________

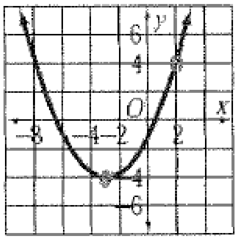
Standard: _________________

5) vertex (-3, 6); point (1, -2)

Vertex: ___________________

Standard: _________________

Use the graph provided to write an equation for a parabola in vertex form and standard form.

1) 

Vertex: $y = \frac{8}{25}(x+3)^2 - 4$ V(-3, -4) P(2, 4)

Standard: $y = \frac{8}{25}x^2 + \frac{48}{25} - \frac{28}{25}$

h k x y

$4 = a(2+3)^2 - 4$

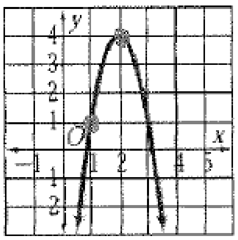
$y = \frac{8}{25}(x^2+6x+9) - 4$

$4 = a(5)^2 - 4$

$y = \frac{8}{25}x^2 + \frac{48}{25} + \frac{72}{25} - \frac{100}{25}$

$\frac{8}{25} = \frac{25a}{25}$ $a = \frac{8}{25}$

$y = \frac{8}{25}x^2 + \frac{48}{25} - \frac{28}{25}$

2) 

h k x y

Vertex: $y = -3(x-2)^2 + 4$ V(2, 4) P(1, 1)

Standard: $y = -3x^2 + 12x - 8$

$1 = a(1-2)^2 + 4$

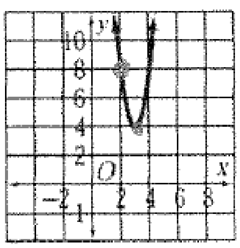
$1 = a(-1)^2 + 4$

$-3 = a$

$y = -3(x^2 - 4x + 4) + 4$

$-3x^2 + 12x - 12 + 4$

$-3x^2 + 12x - 8$

3) 

h k x y

Vertex: $y = 4(x-3)^2 + 4$ V(3, 4) P(2, 8)

Standard: $y = 4x^2 - 24x + 40$

$8 = a(2-3)^2 + 4$

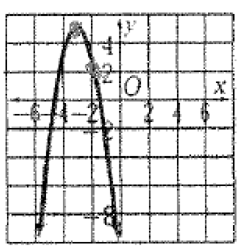
$8 = a(-1)^2 + 4$

$4 = a$

$y = 4(x^2 - 6x + 9) + 4$

$= 4x^2 - 24x + 36 + 4$

$4x^2 - 24x + 40$

4) 

h k x y

Vertex: $y = -3(x+3)^2 + 5$ V(-3, 5) P(-2, 2)

Standard: $y = -3x^2 - 18x - 13$

$2 = a(-2+3)^2 + 5$

$y = -3(x^2 + 6x + 9) + 5$

$2 = a(1)^2 + 5$

$-3x^2 - 18x - 18 + 5$

$-3 = a$

$-3x^2 - 18x - 13$

5) vertex (-3, 6); point (1, -2)

h k x y

Vertex: $y = -\frac{1}{2}(x+3)^2 + 6$

$-2 = a(1+3)^2 + 6$

Standard: $y = -\frac{1}{2}x^2 - 3x + \frac{3}{2}$

$-2 = a(4)^2 + 6$

$-8 = 16a$

$y = -\frac{1}{2}(x^2 + 6x + 9) + 6$

$a = -\frac{1}{2}$

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$y = -\frac{1}{2}x^2 - 3x - \frac{9}{2} + \frac{12}{2}$

$y = -\frac{1}{2}x^2 - 3x + \frac{3}{2}$

Name ______________________

Activity: The Real Quadratics of the United States

1. Find an example of a real world parabolic curve and its dimensions. (You cannot use the Gateway Arch!)
2. Open Geogebra and insert the picture into the file. Include the axis and adjust the scale to correspond to the actual size.
2. Insert a point for the vertex of your picture.
3. Find an additional point that your graph passes through.
4. Calculate the equation in vertex form for the curve using the vertex and the point.
5. Expand your equation into standard form and then pair up. Each partner gives their standard form equation to the other and then attempts to calculate the vertex of their partner's parabola.
6. Perform the requested transformations on each.

Attach a printout of your Geogebra sketches and the figures dimensions.

Your equation:

Vertex: ____________

Point: _____________

Equation in vertex form: _____________________________

Your partner's equation in standard form: ______________________

Vertex of your partner's equation: _____________________

Transformations of your function:

What would happen to the equation if we multiplied the a-value by $\frac{1}{2}$? ____________________

What does this do to your parabola? How would this change affect the surroundings?

How does this affect the item in your picture? ____

____

If you picked up your parabola and moved it to the left 4 and down 2, how does this affect your equation? ____