Lab - Quadratics – Path of a Parabola
Projectile Motion and Quadratic Functions

Math Concept(s):
The student will examine the path of a projectile and explain the motion using a quadratic function. Neglecting air resistance, projectiles follow the path of a parabola in nature.
Source / Text:
Radford.Edu
Developed by:
Adam Keith, Gate City High School, Scott County Schools, Adapted by: Eileen Harris
E-Mail: harrise@svsd410.org Date: Summer Conference 2023

Attach the following documents:

- Lab Instructions
- Student Handout(s)
- Rubric and/or Assessment Tool

Short Description (Be sure to include where in your instruction this lab takes place):
The student will examine the path of a projectile and explain the motion using a quadratic function. This path can be explained mathematically by a quadratic function. Students will work in groups of three to conduct an experiment that involves launching/bouncing a tennis ball an unknown distance and determining the quadratic function that describes the path of their ball knowing only how long it took. The quadratic function will be found in two different ways and the results will be compared to each other to see how closely they resemble.

This lab is best done outside in a courtyard or parking lot.

Lab Plan
Lab Title: Projectile Motion and Quadratic Functions

Prerequisite skills:

- Basic knowledge of conducting experiments, collecting data, and analyzing results.
- Basic understanding of the symmetry of quadratic functions and understand the concept of roots of quadratic functions.
- Know how to find a quadratic function in vertex form and a knowledge of solving systems of equations in two variables.

Lab objective:

- Students will be able to write a quadratic equation given time and two points.
- Work with equations in factored and vertex form.
- Graph equations on coordinate axes with labels and scales.

Standards: *(Note SPECIFIC relationship to Science, Technology, and/or Engineering)*
Mathematics K–12 Learning Standards:

- HS.N.Q.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs. and data displays.
- HS.N.Q.2 Define appropriate quantities for the purpose of descriptive modeling.
- HS.N.Q.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HS.A.SSE.1 Interpret expressions that represent a quantity in terms of its context.*
- HS.A.SSE.1a Interpret parts of an expression, such as terms, factors, and coefficients.
- HS.A.SSE.1b Interpret complicated expressions by viewing one or more of their parts as a single entity.
- HS.A.SSE.2 Use the structure of an expression to identify ways to rewrite it.
- HS.A.CED.1 Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.
- HS.A.CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- HS.A.CED.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context.
- HS.A.REI.1 Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.
- HS.A.REI.10 Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

Standards for Mathematical Practice:

- MP1 Make sense of problems and persevere in solving them.
- MP2 Reason abstractly and quantitatively.
- MP3 Construct viable arguments and critique the reasoning of others.

K-12 Learning Standards-ELA (Reading, Writing, Speaking & Listening):

- Speaking and listening. Comprehension and Collaboration.
- Work with peers to set rules for collegial discussions and decision making.

- Propel conversations by posing and reposing to questions that relate to current information.

Leadership/21st Century Skills:

21st Century Interdisciplinary themes (Check those that apply to the above activity.)

☐ Global Awareness
☐ Financial/Economic/Business/Entrepreneurial Literacy
☐ Civic Literacy
☐ Health/Safety Literacy
☐ Environmental Literacy

21st Century Skills (Check those that students will demonstrate in the above activity.)

LEARNING AND INNOVATION

Creativity and Innovation
X Think Creatively
X Work Creatively with Others
☐ Implement Innovations

Critical Thinking and Problem Solving
☐ Reason Effectively
☐ Use Systems Thinking
☐ Make Judgments and Decisions
☐ Solve Problems

Communication and Collaboration
X Communicate Clearly
☐ Collaborate with Others

INFORMATION, MEDIA & TECHNOLOGY SKILLS

Information Literacy
X Access and Evaluate Information
☐ Use and manage Information

Media Literacy
☐ Analyze Media
☐ Create Media Products

Information, Communications and Technology (ICT Literacy)
☐ Apply Technology Effectively

LIFE & CAREER SKILLS

Flexibility and Adaptability
☐ Adapt to Change
☐ Be Flexible

Initiative and Self-Direction
☐ Manage Goals and Time
☐ Work Independently
☐ Be Self-Directed Learners

Social and Cross-Cultural
☐ Interact Effectively with Others
☐ Work Effectively in Diverse Teams

Productivity and Accountability
☐ Manage Projects
☐ Produce Results

Leadership and Responsibility
☐ Guide and Lead Others
☐ Be Responsible to Others

Teacher Preparation: (What materials and set-up are required for this lab?)

Materials

- Graphing Calculators
- Graph Paper
- Stopwatch
- Tennis Ball

Set-Up Required:

- This lab is best done outdoors.

Lab Organization Strategies:

Leadership (Connect to 21st Century Skills selected):

- **Think Creatively** 1.A.3 Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts - Students find real-world parabolas and must explain how it is and what the parabola might look like in equation form

Cooperative Learning:

Work Creatively with Others 1.B.3 Demonstrate originality and inventiveness in work and understand the real world limits to adopting new ideas - Students will work together to demonstrate knowledge of quadratics and come up with real world applications of the functions as well as the graphs.

Expectations:

- **Communicate Clearly** 3.A.1 Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts - Students must communicate and work together in order to time the toss a ball lab as well as find the quadratic equation of the ball being tossed
- **Access and Evaluate Information** 4.A.1 Access information efficiently (time) and effectively (sources) - Students need to use the time in class given to be able to finish the toss a ball lab as well as make sure they use their resources to find real world applications

Timeline:

- One 70 minute block period

Student Instructions

Projectile Motion and Quadratic Functions

Divide the students into groups of three. Each group will need a stopwatch and a tennis ball. Outside or in a gymnasium, have students complete the following task.

- Student 1 throws ball to student 2 while student 3 uses the stopwatch to time how long it takes the ball to travel from student 1 to student 2. Encourage students to throw the ball high enough so that there is an extended period of time that the ball remains in the air. Student 3 will record the time it takes in seconds for the ball to travel from student 1 to student 2.
- The first question on "data collection" handout provides room to record data and draw the path of the ball. Have the students summarize in their journals the results of the experiment.
- After completion of the task, bring the students back together for whole class discussion. The teacher can facilitate the discussion by moving the students toward the following conclusions:
    - What was the shape of the motion that the ball took in flight from student 1 to student 2? Parabola
    - If the hypothetical x-axis is the horizontal line from the point where student 1 threw the ball to the point where student 2 caught the ball, what are the x intercepts of the ball's flight? (0, 0) and (A, 0) with "A" being the time in seconds the ball was in the air.
    - At what point along the hypothetical x-axis would you expect to find the vertex of the parabola? Half the time the ball was in the air.
    - Knowing that the entire path from student 1 to student 2 took "s" seconds, how long do you estimate it took for the ball to fall from the peak height at the vertex to the hands of student 2? Half the total time.
    - Do you know the height of the ball at the vertex? Not yet at this point, the teacher should remind students that the vertical velocity of a projectile at its peak is 0. Explain to students that this essentially creates a free-fall situation from the vertical peak of the ball to the hands of student 2. For the purposes of this activity, assume the use of customary units. (Depending on the preference of the teacher, this may be modified to use metric units. We are also assuming no air resistance.)
    - Explain to students that the formula for free fall for any projectile is as follows: $d = \frac{1}{2} gt^2$, where d=distance, g=32 feet/second^2, and t=time in seconds. Have students calculate the vertex of their parabola using the formula. Ask which variable in the formula represents the y-value of the vertex? If students have trouble, you can explain that the "d" represents the y value of the vertex.
- Wrap-Up:
    - Have students summarize the information they now know about their parabola. Given that they know the vertex and the roots, ask them to begin thinking about how they will find the quadratic function that represents ball flight.
    - Have students create equations in two or more variables to represent relationships between quantities: graph equations on coordinate axes with labels and scales.

Projectile Motion and Quadratic Functions
Student Handout

Data Collection:

Draw a picture of the ball toss. Be sure to label the height and time of the ball on the axes of your drawing.

Student 1 Student 2

Time for the ball to travel from student 1 to student 2: _____

Questions:

1. What is the path of a projectile in nature?

2. How many different components of velocity does a projectile have at any point in its path?

3. Which component of velocity remains constant?

4. Which component of velocity is always changing?

5. What force causes one of the components of velocity to change?

6. What is the vertical component of velocity when the projectile is at its peak? Free Fall: $d = \frac{1}{2} gt^2$, where d=distance, g=32 feet/second^2 , and t=time in seconds. Calculate the vertex of your ball. Which variable in the formula represents the y-value of the vertex? Homework: Write down thoughts or suggestions for how you plan to find the quadratic function that describes your ball flight.

Summarize the following information about your parabola.

- What is the vertex and the roots
- Begin thinking about how you will find the quadratic function that represents ball flight.
- Create equations in two or more variables to represent relationships between quantities.
- Graph equations on coordinate axes with labels and scales.

Projectile Motion and Quadratic Functions

Number	Element	0	1	2
1	Group Work	The student did not participate in the activity.	The students participated but was disruptive in the completion of the activity.	The student participated in the experiment with good behavior and helped the team complete the activity.
2	Picture	The student did not draw a picture or picture was not labeled appropriately for either height or time.	Student picture was drawn and either height or time was labeled appropriately.	Student picture was drawn and both height and time was labeled appropriately.
3	Question	The student correctly completed 1 or 0 questions	The student correctly completed 2, 3, or 4 questions.	The student correctly completed 5 or 6 questions.
4	Vertex	The student did not do the necessary work to find the vertex of the tennis ball.	The student attempted to find the vertex of the tennis ball but algebraic mistake led to wrong answer.	The student correctly found the vertex of the tennis ball.
5	Equation	The student did not create a equation	The student attempted to create and equation but made mistakes that led to the wrong answer.	The student created equations in two or more variables to represent relationships between quantities.

6	Graph	The student did not create a graph.	The student created a graph without labels and scales.	Graph equations on coordinate axes with labels and scales.