WAMC Lab Template - How High Can You Throw?

Math Concept(s): Quadratic Models
Source/Text: Me

Developed by: Ryan Chute
E-Mail: chute.ryan@gmail.com, rchute@sheltonschools.org
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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):
In an open area, students will throw a tennis ball into the air as straight up as possible and by using algebra find the maximum height the tennis ball achieved.

Lab Plan
Lab Title: How High Can You Throw?

Prerequisite skills: familiarity with quadratic equations in standard form, evaluating quadratic functions, solving one-variable equations, sketching quadratic graphs by hand.

Lab objective: students will be able to use data on their launch height and the total hang time of the tennis ball they throw to algebraically solve for the initial velocity of the tennis ball, and by extension, be able to use the axis of symmetry formula to find the maximum height the tennis ball achieves.

Standards: *(Note SPECIFIC relationship to Science, Technology, and/or Engineering)*

Mathematics K–12 Learning Standards:
F.IF.4: For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship.
F.IF.7: Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
F.B.F.1: Write a function that describes a relationship between two quantities.

Mathematical Practice(s):

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Model with mathematics.
- Use appropriate tools strategically.

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

- RST.9-10.3: Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

- RST.9-10.4: Determine meaning of symbols, key terms, or other domain specific words and phrases as they are used in specific technical context
- RST.9-10.7: Translate quantitative or technical information expressed in words in a text into visual form and translate information expressed verbally or mathematically into words.

K-12 Science Standards:
- 3-PS2-2: Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Technology:
- 1.2.1: Communicate and collaborate to learn with others.
- 1.3.2: Locate and organize information from a variety of sources and media.
- 2.2.1: Develop skills to use technology effectively.
- 2.4.1: Formulate and synthesize new knowledge.

Engineering:
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

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	INFORMATION, MEDIA & TECHNOLOGY SKILLS	LIFE & CAREER SKILLS	Productivity and Accountability
Creativity and Innovation ☐ Think Creatively ☐ 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 ✓ Communicate Clearly ✓ Collaborate with Others	Information Literacy ☐ Access and Evaluate Information ✓ Use and manage Information Media Literacy ☐ Analyze Media ☐ Create Media Products Information, Communications and Technology (ICT Literacy) ☐ Apply Technology Effectively	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	☐ 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:
- Tennis balls
- Stopwatch or phone
- Notebook and pen/pencil for note taking
- An open area or field

Set-Up Required:
Checking with school officials that any area/field that is needed is clear for use for that period.

Lab Organization Strategies:

Leadership (Connect to 21st Century Skills selected): Students will have the opportunity to rotate roles when doing their 'field' work. Back in the classroom when students are working on their algebraic work to find their tennis ball's initial velocity, time when the maximum height occurred, and the actual maximum height, students are encouraged to assist one another in checking the algebra of their teammates in order to ensure accuracy.

Cooperative Learning: Students are organized into roles through which they rotate during their field work. Each student has the opportunity to work with each of the materials. Later on, students will work in small groups of 3 on their own algebraic work and then check their teammates' algebra to ensure accuracy of their results.

Expectations: Students are expected to be meaningfully contributing to their groups in some way by taking on a role within their group. They are also expected to show good teamwork skills by showing flexibility, patience, and encouragement to their group members as needed. This also extends to the algebraic worktime that follows getting the field data, where students work independently to find the maximum height they can throw a tennis ball while also checking their teammates' work.

Timeline:
Introductory Video: 3-5 minutes
Introduction of Lab & Revisiting Projectile Motion: 10 minutes
Running the Lab: 20-30 minutes
Doing the Algebra: 10 minutes
Follow-Up Discussion and Data Collection: 10-15 minutes (*note: if you have 55-minute periods, this can be done the next day as a follow-up)

> *note: an interesting extension is to get everybody's hang time + max height, and to plot all of these points on Desmos to see the relationship between hang time and maximum height. The results and ensuing discussion should be… interesting.

Post Lab Follow-Up/Conclusions:

Discuss real world application of learning from lab: what can we infer about initial velocity and initial height? How do these affect the maximum height a tennis ball can achieve? Do you think it mattered if a ball was thrown straight up in the air vs. being thrown in a direction?

Career Applications: what careers do you think would need to know about projectile motion and how objects move through gravity?

Optional or Extension Activities: plot all points of (hang time, maximum height) collected from students on Desmos or Geogebra. What kind of pattern do these points make: linear, exponential, quadratic, other? Why do you think that is?? If you know how, try to fit a regression to these points to assist in understanding.

HOW HIGH CAN YOU THROW?

My group members are: ____.

Before doing anything else, make a prediction for yourself: between what two heights do you think you can throw? The lower number in your range will represent the absolute minimum that you know you could achieve, while the higher number will represent the absolute maximum that you could ever achieve.

I think the highest height I can throw a tennis ball is between _______ and _______ feet.

Now, onto the experiment!!

Materials Needed

- Yardstick
- Tennis ball
- Stopwatch/phone
- Paper and pen(cil)

Experiment Design:

1) The Thrower throws the tennis ball as high as they can into the air.
   The throw should be as straight up into the air as possible.
2) The Observer will observe and measure from what height the ball leaves the thrower's hand by using the yardstick.
3) The Timer+Recorder will time how long the ball is in the air, and record the results on the Thrower's sheet of paper.
4) Each Thrower will get 5+ attempts at throwing a tennis ball in the air.
5) Each group member will rotate roles so that they take on each role once.

Trial #	1	2	3	4	5
Release Height (ft)					
Total Hang Time (sec)					

Average Release (Initial) Height: _____________ Average Total Hang Time: _____________

How High? - Work Time

Relevant Formulas:

$$h(t) = -16t^2 + v_0t + h_0$$
where t is time (in seconds), v_0 is the initial velocity, and h_0 is the initial height

$$x = -b/2a$$
for the axis of symmetry of any parabola

Now that you have your numbers, please do the following:

1. Using the projectile motion formula

use your *average* hang time to solve for the initial velocity.

2. Now that you have an initial velocity, find the axis of symmetry to find the time at which the tennis ball reached its maximum height.

3. Use the time associated with the axis of symmetry to then find the maximum height the tennis ball reaches.

4. Repeat steps #1-3, but use your *longest* hang time from your trials.

Fill in the table below with your findings from your work in steps #1-4 above.

	Time of Maximum Height	**Actual Maximum Height**
Average Hang Time		
Longest Hang Time		

Once you have finished your own work, check with your groupmates to see how your results compare, to make sure your own results make sense, and to see if you can offer them any help if needed.