Python Lesson 2: Quadratic Functions and Projectile Motion
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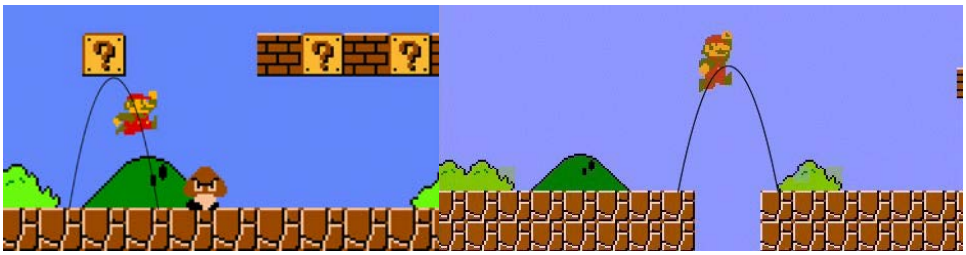
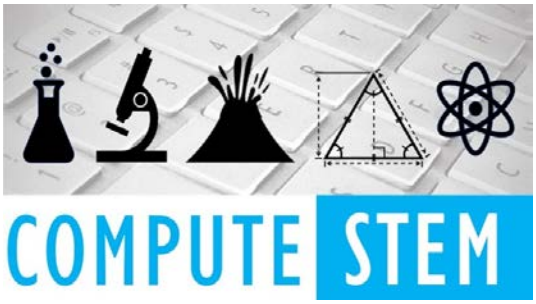
Engage:
Show a Super Mario clip (https://www.youtube.com/watch?v=goYnB61nrjg). In the video, students will see that quadratic functions are used in this game. Every time Mario jumps, it creates a parabola. If he jumps too early, he won't make it. This is because of how quadratics function (their vertex, axis of symmetry, maximum/minimum values/roots) which deals with projectile motion. After students watch the clip, we will ask them to come up with more examples in the real world where parabolas are found.

Explore:

Students will be seated in groups of about 4. Each group will be given the 2 images above, with values for the coordinates of Mario's position on the screen before each jump, in the middle of each jump, and after Mario lands. Students will see that the height of each jump is the same (16 units), but its distance varies based on Mario's speed.
Using the given coordinates, students will first have to calculate the equation for each parabola by plugging the vertex and one other point into Vertex Form.

Next, students will write the code "for the game" to dictate Mario's position on the screen when he jumps. This process will follow the same steps that they used above, but translated into code and using variables.
As a practice of peer programming, the work is divided into 4 steps - each requiring knowledge of both quadratic equations and the Python language. The group will assist each other, but are responsible to work out a few lines of code each. This will also require that students first agree on variable names that they will use. This reinforces good coding practice, while also requiring that they review the different variables used in Vertex Form of a quadratic and their meanings (a, h, and k).

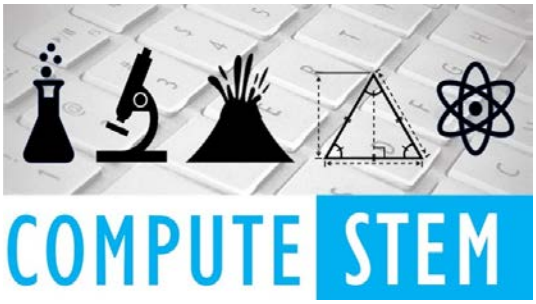


The Python file should include the following steps:

1. Request and save the x-value of the vertex and both coordinates for a second point
2. Calculate the value of ‘a’ using the values entered by the user and 24 for k.
3. Print the general-form equation in a readable way, with the correct values
4. Ask for a value of x. Calculate and print Mario’s height at that x-value

An example of student work may look like:

```
#STEP 1: Request coordinates

h = float(input('Enter the axis of symmetry.'))    #This is the y-value of the vertex.
x1 = float(input('Enter the x-value of another point.'))
y1 = float(input('Enter the y-value of another point.'))

#STEP 2: Calculate 'a'

k = 16   #This is the height of every jump.
temp = x1-h**2
a = y1-k/temp

#STEP 3: Print the General-Form Equation

print('Mario\'s path will be the equation  y= '+str(a)+' (x-'+str(h)+')^2 +'+str(k))

#STEP 4: Calculate Y for a specific X

X = float(input('Enter an x-value for Mario\'s position.'))

ANSWER = X-h
ANSWER = ANSWER**2
ANSWER = ANSWER*a+k

print('Mario will be '+str(ANSWER)+ ' units off the ground.')
```



Explain:
Students will gain a deeper understanding of quadratic functions by connecting what they already know to the code that they have created. At this point, students will have practiced the basics of quadratics such as factoring, real world application problems, and interpreting what each part of the equation tells you in context of the problem. Using the code that they created, they will substitute in different positive and negative values to test how that changes the the parabola. As they work, they will keep track of their findings using a graphic organizer. Each group of students will be asked to explain a different component of the quadratic function. (Ex: What happens to the function when a, b, or c is positive/negative, bigger/smaller, etc.)

Elaborate:
The elaborate portion of our lesson will ask students to take a closer look at the relationship between quadratics and projectile motion, similar to the warm up video. Given a screenshot from a different game, students will need to be able to do the following things: identify/interpret the vertex, identify/interpret the maximum and/or minimum values of the function, identify the *x* and *y* intercepts, and identify the intervals over which the function is increasing or decreasing. The main skill to be taken away from application problems is to be able to interpret the contextual meaning of the items stated above, and associate these with parts of the equation.
To demonstrate understanding, students will be asked to answer the following questions about each new example game:
What value(s) must be changed for your code to represent this game? If both characters has the same x-value on the screen, would you expect this new code to result in higher or lower y-values? Why?
Students' answers, and their ability to interpret the meaning of a particular quadratic using the relevant values, will also serve as one of the many points of evaluation.

Evaluate:
Students will be evaluated throughout the lesson. The teacher will observe student participation, check student's codes, ask students to share out their responses to reflection questions, and listen to group conversation.