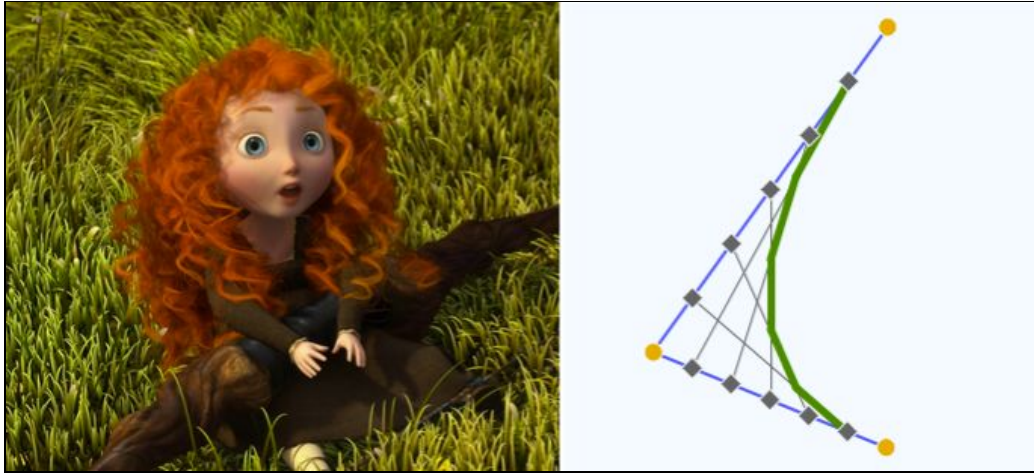


# ENVIRONMENT MODELING: FIRST LESSON ([link to lesson](#))



**Standards alignment:**

**NGSS:**

[HS-PS2-1](#)

**Common Core:**

[5.G.A.2](#), [8.F.B.5](#),

[6.EE.C.9](#), [8.EE.B.5](#)

## Summary/Overview:

When creating the virtual worlds that their characters live in, technical artists at Pixar look to the natural world for inspiration and mimic it using mathematical formulas. This lesson dives into the math that was used to create the landscapes in "Brave," starting with a single blade of grass.

**Lesson Structure:** This lesson contains 7 videos, 5 practice exercises which alternate back and forth. One way to run this is to watch and discuss all videos as a group (using a screen at the front of the room) while letting students return to their computers to do the exercises when required.

## Total Time Recommended:

Approximately 60-90 minutes to complete the videos and exercises.

**Age:** Grade 5 - infinity and beyond!

## Objectives:

In this lesson, students will:

- Explore how realistic blades of grass are modeled using parabolic arcs.
- Design their own blade of grass using midpoints and simulate it as a flowing field.

## Materials Needed:

- Indoor classroom, lab, or open space with seating and access to the Internet. Space should have enough seating, ideally facing a teacher/facilitator's projection screen.
- Teacher/facilitator should have a computer connected to a large monitor or projector and speakers.
- This lesson assumes that each student or pair of students will require a device to access the lessons online.

## VIDEO 0: Introduction to Parabolic arcs (length: 2 mins)

**Instructions:** What do parabolic arcs have to do with blades of grass? Have everyone sit where they can see the screen. From the lesson page, play the video “Introduction to Parabolic arcs.” When the video ends, start a discussion with your group using questions below.

### Key terms / Vocabulary:

- **Parabola** - There are many ways to define a parabola. One definition is it's the curve created when you graph a quadratic equation such as  $x = y^2$

### Discussion Questions (3-4 minutes):

- **Q:** Did you ever think that math would be used to create plant life? What are some other unexpected uses of math you've heard about?
- **Q:** Does a parabola describe all of the qualities of a blade of grass?
- **A:** No, just the curve of the spine. We still need to add a thickness and a color.

## VIDEO 1: String Art (length: 3 mins)

**Instructions:** Find out how we can make curved lines using straight ones using the string art construction. Have everyone sit where they can see the screen. From the lesson page, play the video “String art.” When the video ends, start a discussion with your group using questions below.

### Key terms / Vocabulary:

- **Parabolic arc** - a section of a parabola
- **Control Polygon** - 3 points used to control a parabolic arc

### Discussion Questions (3-4 minutes):

- **Q:** In addition to the curve, what are some of the attributes needed to make grass look believable?
- **A:** Width, color, and how it moves.
- **Q:** How does Pixar make parabolic arcs more intuitive for artists?
- **A:** By using 3 control points, or a “control polygon.”
- **OPTIONAL:** [Click here](#) to see Vi Hart's video on this technique.

## **PRACTICE: String art construction (5 - mins)**

**Instructions:** Create a parabola by adding strings between two control arms. After students are nearly finished, check for understanding before moving on to the next video (remind students they can restart by clicking on the button in the lower right corner of the simulation window)

### **Exercise Questions:**

- **Q:** What did you learn about string art construction in this exercise?

## VIDEO 2: Midpoint formula (length: 3 mins)

**Instructions:** Explore how midpoints are used to describe the "string art construction." Have everyone sit where they can see the screen. From the lesson page, play the video "Midpoint formula." When the video ends, start a discussion with your group using questions below.

### Key terms / Vocabulary:

- **Midpoints** - a location in between two coordinates

### Discussion Questions (3-4 mins):

- **Q:** What happens to your parabolic curve when you increase the number of midpoints and connecting strings?
- **A:** It gets smoother.
- **Q:** True or false: By using the midpoint formula repeatedly, you can get multiple, evenly spaced points along a line.
- **A:** True
- **Bonus Question:** What does "sub" stand for?
- **A:** It's short for subscript, which means writing the letter smaller and lower down.

## **PRACTICE: Midpoint formula (length: 10 mins)**

*4 problems covering basic concepts*

**Instructions:** After students are nearly finished, check for understanding before moving on to the next video (remind students they can find help in the hints for each question.)

### **Exercise Questions:**

- **Q:** What did you learn about calculating a midpoint in this exercise?

## **VIDEO 3: Parabolic arcs (length: 2 mins)**

**Instructions:** Are we really creating parabolic curves using this construction? Let's gain some insight first. Have everyone sit where they can see the screen. From the lesson page, play the video "Parabolic arcs." When the video ends, check for clarifying questions before proceeding to the next exercise.

## **PRACTICE: Parabolic curve matching (length: 10 mins)**

Drag the **three orange control points** so that the **blue** curve is exactly on top of the **green** parabolic arc.

**Instructions:** After students are nearly finished, check for understanding before moving on to the next video (remind students they can find help in the hints for each question.)

### **Exercise Question:**

- **Q:** What did you learn about parabolic curve matching in this exercise?



## VIDEO 4: Modeling grass (length: 2 mins)

**Instructions:** Next let's build a blade of grass using a parabolic arc as a spine. [Click here](#) to review perpendicular lines. Have everyone sit where they can see the screen. From the lesson page, play the video "Modeling grass." When the video ends, check in with your group using a couple questions below.

### Key terms / Vocabulary:

- **Skeleton lines** - Lines that cut across the blade of grass at 90 degree angles.

### Discussion Questions (3-5 mins):

- **Q:** Why would you want to change the color of each blade of grass in a scene?
- **A:** One idea is that it's a good way to show that each blade is unique and different from the others, making it more convincing.
- **Q:** When you adjust the width of a blade of glass, what happens to the skeleton lines?
- **A:** They get shorter or longer.

## **DESIGN CHALLENGE: Modeling grass (length 5-10 mins)**

*Build a blade of grass using the string art construction.*

**Instructions:** Demonstrate this to show how to step through the design challenge windows. After students are nearly finished, see if anyone would like to share their blade of grass. Check for understanding before moving on to the next video.

### **Exercise Questions:**

- **Q:** What did you learn about modeling grass in this exercise?

## VIDEO 5: Animating grass (length: 3 mins)

**Instructions:** Finally, let's bring our parabolic arc to life! Have everyone sit where they can see the screen. From the lesson page, play the video "Animating grass." When the video ends, start a discussion with your group using questions below.

### Key terms / Vocabulary:

- **Modeling** - Defining the shape of something
- **Shading** - How to create a color
- **Animation** - How to make the blade of grass move
- **Keep Alive** - A subtle movement that makes something look alive instead of static and dead

### Discussion Questions (2-3 mins):

- **Q:** What kind of weather would require a simple "keep alive" movement?
- **A:** Calm day, not a windy day
- **Q:** Can you think of any other types of surfaces where "keep alive" would be used?
- **A:** Hair, trees, plants, sand, fur...
- **Q:** What are some different ways you can add variation to your blade of grass?
- **A:** Start the animation at a slightly different time, use randomness

## DESIGN CHALLENGE: Animating grass (length 5-10 mins)

*Animate your grass!*

**Instructions:** Use this interactive to see if you can animate two different shots. One with just a little bit of gentle Keep Alive, like on a calm day, and another that looks like a very windy or stormy day. After students are nearly finished, ask if they'd like to share their animations. When finished, check for understanding before moving on to the next video.

### Exercise Questions:

- **Q:** What did you learn about modeling grass in this exercise?

## **VIDEO 6: Getting to Know Tony DeRose (length: 5 mins)**

**Instructions:** Have everyone sit where they can see the screen. From the lesson page, play the video “Getting to Know Tony DeRose.” When the video ends, start a discussion with your group using questions below.

### **Discussion Questions (5-10 mins):**

- **Q:** What inspired you about Tony’s experience?

*If you’d like to explore this further, we have an hour long hands-on activity that extends this lesson here:*

## **Hands-on activity: String Art. (30-90 mins)**