VIRTUAL CAMERAS: FIRST LESSON (link to lesson)

Standards alignment:
NGSS: MS-PS4-2, HS-PS4-5, HS-LS1-2
Common Core: 6.RP.A.1, HSA.SSE.A.1

Summary / Overview:
Just as live-action movies are made using cameras, Pixar uses virtual cameras within the computer environment to “film” their movies. These virtual cameras, with optics that behave like real lenses, are placed in a shot by cinematographers who make artistic choices based on what they want each shot to convey.

Lesson Structure: This lesson contains 6 videos and 6 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 minutes to get through this lesson

Age: Grade 5 - infinity and beyond!

Objectives:
In this lesson, students will:

- Learn how cameras function
- Learn how cameras are used to achieve various artistic effects
- Learn what drives the camera choices made by Pixar’s cinematographers, and how they apply the physics of light and lenses to recreate the ways that actual cameras capture real life.

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 projector and speakers.
- Students can keep a note cards next to their computer to jot down notes and questions they might have while watching the videos.

VIDEO 1: Introduction to Virtual Cameras (length: 4 mins)

Overview of Virtual Cameras.

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

Key terms / Vocabulary:

- **Perspective:** the point of view of the camera
- **Depth of Field:** depth of the region in our scene which is in focus

Discussion Questions (5 mins):

- **Q:** How does lens choice affect the image?
- **A:** focus, perspective
- **Q:** How can lens choices support the emotion of a story or scene? Can you think of examples from other films?
- **Q:** How does using a long lens vs a wide lens change the feeling of perspective?
- **A:** makes farther objects feel closer, or farther objects farther
- **Q:** When would you want to use a wide angle lens (such as a 18mm lens)?
- **A:** When you want a wide field of view, or to make objects appear farther from the camera.
- **Q:** What two things should you consider when deciding on how to shoot your scene?
- **A:** lens choice and placement of the camera

VIDEO 2: What is a pinhole camera? (3 mins)

How cameras capture images using an aperture.

Instructions: From the lesson page, play the video “What is a pinhole camera” When the video ends, start a discussion with your group. Here are a few questions to get you started:

Key terms / Vocabulary:

- **Camera obscura:** darkened room with small hole in the wall
- **Pinhole camera:** a simple design of a light-tight container with an image plane opposite the aperture.
- **Image plane:** the surface inside a camera where light rays hit
- **Aperture:** the size of hole that lets light into the camera

Discussion Questions (4-5 mins):

- **Q:** What does “camera obscura” mean?
- **A:** Darkened room with small hole in the wall
- **Q:** What room would you turn into a camera obscura?
- **Q:** What are some other types of pinhole cameras?
- ***A:** Google image search on screen*
- **Q:** Why does the image appear upside down and backwards?
- **A:** Points of light travel in a straight line
- **Q:** What is the connection between aperture and focus?
- **A:** Smaller aperture = sharper focus

EXERCISE 1: Simple Pinhole Camera (4-6 minutes)

Instructions: Try changing the aperture in the pinhole camera simulation below and taking an image. After experimenting with it for a while, answer the 7 questions provided.

Additional questions:

- **Q:** When do light rays NOT travel in a straight line?
- **A:** When they are bent or refracted by the curve of a lens
- **Q:** How are your eyes like a camera? (see this KA lesson on the structure of the eye)

VIDEO 3: Focal Distance (length: 2 mins)

What happens if we change the distance between our aperture and image plane?

Instructions: Have everyone sit where they can see the screen. From the lesson page, play the video “Focal Distance.” When the video ends, start a discussion with your group using questions below.

Key terms / Vocabulary:

- **Focal distance:** The distance between the aperture and the image plane
- **Field of view:** How wide our perspective is depending on the focal distance

Discussion Questions (3-4 minutes):

- **Q:** Why does our image get blurrier when the aperture gets bigger?

  A: Light from various parts of the scene hit the same spot on the image plane
- **Q:** How does decreasing the distance between the image plane and the aperture effect the image?

  A: wider field of view
- **Q:** Conversely, when we increase the distance between the image plane, but make the size of the aperture SMALLER, what is the effect on the image?
- **A**: It is a narrow field of view

EXERCISE 2: The effect of focal distance (length: 5 mins)

Below is a simulation of a pinhole camera. Try capturing images using different focal distances and then answer the questions underneath.

Instructions: This might be fun to do as a class, or demonstrate how to use the simulator, showing what happens when you adjust the aperture and focal distance variables, then have individuals try their hand at the two questions.

Exercise questions (2-3 mins)

- **Q:** What aperture setting(s) yield the sharpest focus, regardless of focal distance?
- **A:** 1,2
- **Q:** How long can the focal distance be before the tree is cropped?
- **A:** roughly 210

VIDEO 4: Camera lenses (4 mins)

Now we'll add a lens to our camera and explore the idea of an f-stop.

Instructions: Have everyone sit where they can see the screen. From the lesson page, play the video “Camera lenses.” When the video ends, start a discussion with your group using questions below.

Key terms / Vocabulary:

- **Lens:** allows us to bend light rays with a wide open aperture
- **Focal point:** the point where parallel light rays converge
- **Focal length:** the distance between lens and image plane that focuses light rays on the image plane
- **Wide angle lens (28mm):** yields a wide field of view
- **Long lens: (120mm):** yields a narrow field of view
- **F stops:** ratio of focal length of lens to diameter of the aperture

Discussion Questions (2-3 mins):

- **Q:** True or False: A lens can actually BEND light!
- **A:** True, that’s how you get light rays to converge
- **Q:** If you increase the curvature of a lens (like a “fish-eye” lens) how does that affect the focal point?
- **A:** It focuses light rays very close to the lens
- **Q:** How are F stops calculated?
- **A:** Divide focal length by diameter of aperture

EXERCISE 3: Camera Lenses (length: 10-15 mins)

The diagram below shows rays from a distant object hitting a lens and being bent, or refracted, onto an image plane.

Instructions: Have students work through these 8 problems individually, then regroup to check for understanding.

Exercise questions:

The final question is a great point for you to stop and calculate together. Ask for a volunteer to demonstrate the equation for how to calculate the size of the aperture on two different lenses. The results might surprise some who assumed that all F-stops are the same physical size.

1 / 4

$$\text{f-stop} = \frac{\text{focal length}}{\text{aperture diameter}}$$

2 / 4

We can rearrange the equation to get:

$$\text{aperture diameter} = \frac{\text{focal length}}{\text{f-stop}}$$

3 / 4

So for the 50mm lens, the diameter is: $\frac{50\text{mm}}{8} = 6.25\text{mm}$

For the 120mm lens, the diameter is: $\frac{120\text{mm}}{8} = 15\text{mm}$

4 / 4

So the aperture of the 120mm lens is wider.

Discussion questions: (5 mins)

- **Q:** What's another word for bending light?
- **A:** Refraction
- **Q:** Describe how lens curvature affects field of view
- **A:** The bigger the curve, the more light rays are refracted and the wider the field of view
- **Q:** What's another word for for image plane?
- **A:** Image sensor or film
- **Q**: What's the difference between focal distance and focal length?
- **A:** Focal distance is the distance between the aperture and the image plane (where the image sensor is.) Focal length is the distance between the front of the lens and the point (or plane) where light rays focus (this may or may not be on the image plane!)

VIDEO 5 - Depth of Field (length 4 mins)

In this video we'll explore why regions in our scenes can go "out of focus." The region of our scene which is in focus is called depth of field.

Instructions: Have everyone sit where they can see the screen. From the lesson page, play the video “Depth of Field.” When the video ends, start a discussion with your group using questions below.

Key terms / Vocabulary:

- **Circles of confusion:** Light rays that haven’t been focused to a point on the image plane
- **Depth of Field:** The "depth" of the region within an image which is in focus

Note: Search “Bokeh” for examples of how to use the circles of confusion creatively!

Discussion questions (5 mins):

- **Q:** How can you get a deep depth of field?
- **A:** using a small aperture / bigger F stop
- **Q:** How can you get a shallow depth of field?
- **A:** increase the size of the aperture / smaller F stop
- **Q:** Why are some images out of focus?
- **A**: the refracted light rays from the lens come to a point before or beyond the image plane
- **Q:** Why are parts of images out of focus while other parts are in focus?

  A: the refracted light rays converge on the image plane, while things closer or further away from the lens converge before or beyond the image plane

EXERCISE 4: Depth of Field (length 5-8 mins)

Use the camera controls to change the scene. When the scene meets the requirements, you'll get a green tick and you can click the check answer button.

Discussion Questions (2-3 mins):

- **Q:** Did San Francisco really ruin pizza by putting broccoli on it?
- **Q:** Which F-stop number gives you the thinnest slice of focus? 2.8 or 16?
- **A:** 2.8. Remember, the smaller the number, the bigger the hole
- **Q:** How does decreasing the f-stop (increasing the size of the aperture) decrease the depth of field?
- **A:** When you let more light into the aperture, it increases the size of the circles of confusion. So as you move away from the image plane it gets blurry faster

VIDEO 6: Storytelling with Camera (length: 3 mins)

How are lens choice, camera movement & depth of field used to increase artistic impact of our films? We'll also explore how we get things wrong on purpose.

Instructions: Have everyone sit where they can see the screen. From the lesson page, play the video “Storytelling with Camera.” When the video ends, start a discussion with your group using questions below.

Discussion Questions (5 mins):

- **Q**: How does Patrick use depth of field in storytelling in Blue Umbrella?
- **A:** He used a longer lens to create a distance between camera and subject
- **Q:** How did he use camera movement to help viewers distinguish between inside and outside worlds in the movie “Inside Out”?
- **A:** The outside world looks more organic, inside world looks predictable and formal.
- **Q:** How can the use of focus help to add to the imperfection of Riley’s real world?
- **A:** in Act 2 and Act 3, they purposefully misfocused to add to the feeling of imperfection
- **Q:** Can you think of any other films or scenes that are memorable to you because of the use of camera focus, depth of field, and movement?

EXERCISE 5: Scene Composition (length 5-10 mins)

Instructions: Use the tool below to compose two scenes. Experiment with different camera settings to see what effects you can create. You can switch between two scenes using the dropdown menu above the image and choose the camera setting with the sliders below the image.

Once you have experimented with the camera tool, try to answer the 4 questions correctly.

Discussion Questions (5 mins):

- **Q:** How does using a long lens (such as a 200mm lens) affect the feeling of a scene?
- **Q:** When would you want to use a wide angle lens (such as a 28mm lens)?
- **Q:** If you wanted a viewer to focus on a particular element in a scene, what sort of lens and f-stop might you use?
- **Q:** When might you want more of the background to be in focus?
- **Q:** Why does decreasing the focal length make the background look farther away?
- **A:** It allows for the curve of the lens to take in a wider field of view, pushing the background further away from the image plane
- **Q:** Does anyone have questions from your notecards you would like us to review as a group? (collect and go over out loud)

VIDEO 7: Getting to know Eben (length 3 mins)

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

Discussion Questions (5 mins):

- **Q:** What inspired you about Eben’s path?
- **Q:** What surprised you about the history of Pixar?