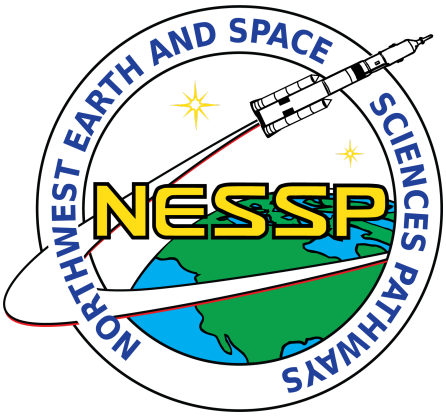


NESSP Mini-Mission

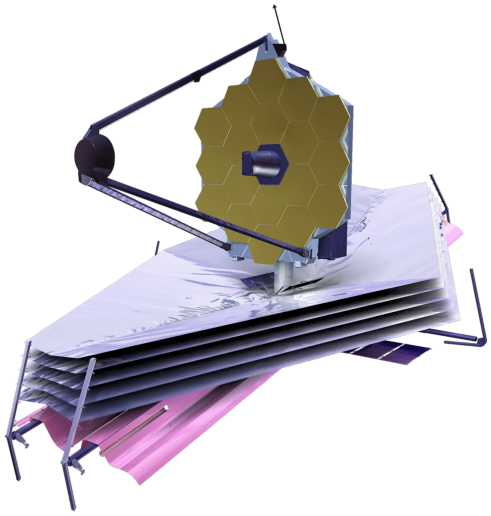
James Webb Telescope

Get Ready For Launch!

The Mission: Get students excited about the upcoming launch of the James Webb Space Telescope (JWST) with hands-on NASA-themed activities.

Northwest Earth and Space Sciences Pathways (NESSP) has three lessons ready for deployment. Try one lesson, or do them all! Do them consecutively, or any order you want!

- **Lesson 1: Launch Code Quest:**
  - Students will work collaboratively to learn the history of JWST and how it will use infrared light to study its main targets throughout the universe.
- **Lesson 2: Telescope and Optics:**
  - Students will compare a desktop telescope to Hubble and JWST, and learn about light refraction and magnification with lenses.
- **Lesson 3: Build-Your-Own Telescope:**
  - Students will investigate the main elements of a space telescope and design their own with an iterative and collaborative approach.
- **Lesson 4: Science Goals Scavenger Hunt:**
  - Students will use the World Wide Telescope to hunt down images of potential targets for the JWST to observe and make an 18-hexagon collage!



Grade Levels: 6-10

Ways to teach these lessons:

The lessons are designed to be taught in-person in a classroom environment; however, each can be modified for informal or remote learning environments.

Limited on Time?	Don't have the materials?	Teaching remotely?
No need to do every part of the lessons! **Lesson 1:** Just do the game in the Explore portion. **Lesson 2:** Jump into the Evaluate portion. To introduce the telescope, use the PhET Bending Light simulation to demonstrate the behavior of a lens. **Lesson 3:** Focus on designing the telescope with Parts 3-5 of the Explore, Explain, and Elaborate. **Lesson 4:** Just do the Engage and Explore.	**Lessons 1, 3, and 4:** These lessons do not require any special equipment other than a printer with colored ink. If you don't have AV equipment, skip the videos and slides. For Lesson 3, consider printing graphics on the components of the list of telescopes from web pages in advance. **Lesson 2:** This lesson uses Celestron FirstScope Telescopes and hand-held lenses. If you have not borrowed these items from NESSP, have students use the PhET Bending Light instead of lenses in the Explore and skip the Evaluate portion.	See the green box at the end of each lesson for guidance on adapting these lessons to a remote learning environment utilizing video conferencing software. **Lesson 4** is designed to be easily adapted to remote learning using Google Slides and Docs.

Materials:

A primary goal of NESSP is to provide supplies and experts to educators in underserved communities. All of the materials listed on the first page of each lesson are available for loan. Please do not hesitate to request supplies and access to an experienced educator in your region by filling out the form here: https://nwessp.org/programs/mini-missions/

Resources for additional information:

There are numerous sites that students and educators can use to learn more about JWST. We suggested starting with the list below.
https://www.jwst.nasa.gov/
https://en.wikipedia.org/wiki/James_Webb_Space_Telescope
https://webbtelescope.org/

Providing feedback, corrections, and success stories:

NESSP strives to develop material and programs that are effective for teachers and students. Please feel free to share your feedback by emailing us directly at info@nwessp.org.

We want to see NESSP in action!

Share photos, videos, and comments related to your experience by emailing us or tagging us on social media:

- Email: info@nwessp.org
- Instagram, Facebook, Twitter, and YouTube:: @nwessp

Now, get ready for a successful launch.....

Lesson 1: Launch Code Quest

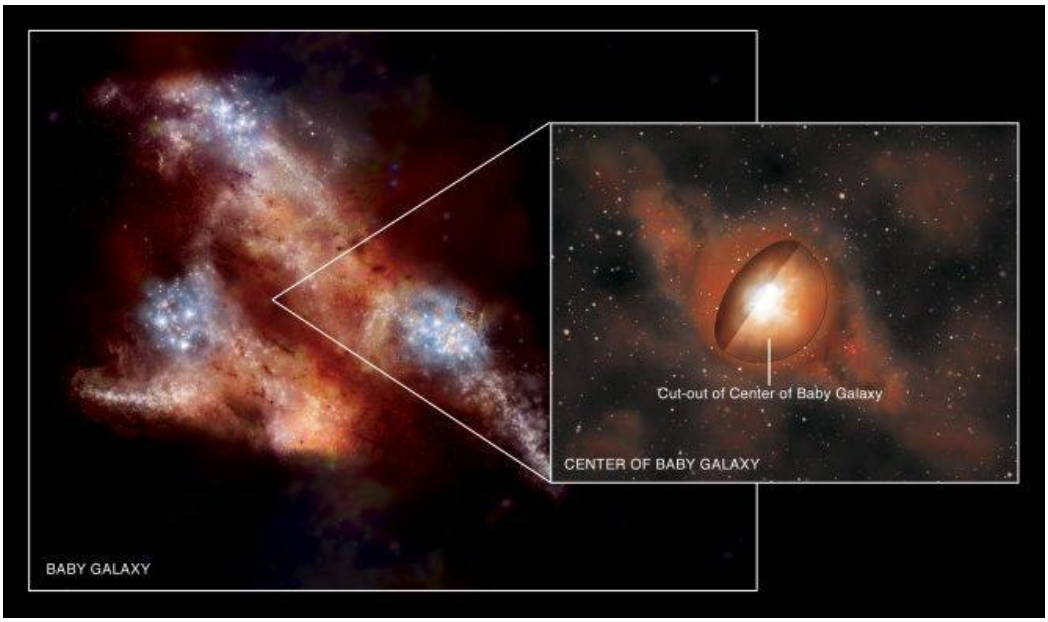


Image Credit: NASA/JPL

Lesson Level Question:

How will the James Webb Space Telescope use the electromagnetic spectrum to learn about celestial bodies in our universe?

Lesson Summary:

Students will gather information about one of three topics: 1) the James Webb Space Telescope (JWST), 2) the electromagnetic spectrum, or 3) celestial bodies. Using this information, they will individually solve puzzles to obtain clues (like a name or description of an object). By collaborating and sharing the clues, students will receive a 'launch code,' which will be used to send the JWST into space! Students must do this task within a limited time, or else NASA will delay the launch. Students will then discuss information they learned throughout the activity, and determine a solution to the Lesson Level Question outlined above. The information transfer mode is partially through reading a newspaper clipping, and partially through students teaching one another about their specialty topic.

Materials:

- Three Folders (1 Space Telescope Puzzles, 1 Scientist Puzzles, and 1 Data Signal Puzzles), per group
    - Inside each folder, include prepared puzzles (directions and pieces). Preparing the puzzles will take some time. See the Explore preparation for files and notes on printing instructions.
- JWST Newspapers "Space Times", 3 per group
- Teacher Overview and Scripted Introduction

Background:

After many rescheduled launch dates, the James Webb Space Telescope (JWST) launched on December 25th. Now we await the first images to be released in the summer of 2022.

In the meantime, students completing this activity will have the opportunity to solve puzzles using information gathered from a newspaper-style information packet. In this collaborative puzzle game, students will learn about JWST, the electromagnetic spectrum, and different celestial bodies as they work through puzzles about these topics.

At the beginning of this activity, students should already understand a few basic terms and use them as building blocks for information gathered. These terms include space, telescope, celestial, spectrum, and radiation. In addition to these terms, students should be proficient in the mathematical topic of the order of operations and read at least at a 6th-grade level.

To learn more about the James Webb Space Telescope we invite teachers to read Space Times before introducing the lesson.

Engage (8 min):

Preparation:

1. Prepare to show a YouTube video to the entire class.

Directions:

1. Ask students, "Have you heard of the James Webb Space Telescope before? If so, what do you know about it?"
    a. Take responses from the group. If nobody has anything to share, ask students, "Who has heard of the Hubble Space Telescope? What do you know about Hubble?"

2. Explain to students, "We are going to watch a video, and I want you all to learn and remember at least one fact from it." Show the students this video on JWST: https://www.youtube.com/watch?v=6VqG3Jazrfs.

3. Ask students again, "Now, what did you learn about the James Webb Space Telescope from this video?"
    a. Take responses from the group. Encourage students to focus on the telescope, but information about celestial bodies, the electromagnetic spectrum, or the Hubble Space Telescope is also welcomed.

Explore (45 min):

Preparation:

1. Read through the Teacher Overview and Scripted Introduction.

2. Split students up into groups of 10-12. Assign 2-4 students in the role of "scientists" and 2-4 students in the role of "space telescopes." The remaining students will be in the position of "data signal."

3. Print out the puzzles. *This will take some time if printing your materials.* Students will need to write some puzzles; the teacher should print these puzzles on plain paper every time the game is played. Alternatively, the teacher can place these papers into plastic sheet protectors for students to write on using whiteboard markers. Other puzzles, the game board, and game tiles should all be printed on cardstock to be reused. Since James Webb's mirrors are gold, we recommend printing the hexagonal tile pieces on yellow or gold cardstock. However, all puzzles and the game board/tiles can also be printed on regular paper.

   Printing Instructions

   When you are ready to print out all of the materials for the James Webb Launch Code Quest, download each of the following PDF documents:

   1. Single Sided Cardstock Puzzles Combined, 1 per group
   2. Double Sided Cardstock Puzzles Combined, 1 per group
   3. Single Sided Plain Puzzles Combined, 1 per group
   4. Double Sided Plain Puzzles Combined, 1 per group
   5. Data Signal Single Sided Gold Puzzles, 1 per group
   6. Space Times newspaper, 3 per group

   See the Printing and Compiling Instructions for instructions for building the game.

4. Prepare the data signal, space telescope, and scientist folders. Note that each printed puzzle sheet has a footnote that indicates the appropriate folder for the puzzle or information sheet. Cut out each puzzle/instruction slip and place them in the proper folder. It may be best to keep small pieces and instructions together by placing corresponding instructions and game pieces into individual plastic bags. Double-sided puzzles should line up correctly after printing.

5. Adjust the classroom.
   a. Place two desks facing one another and separate by a distance of approximately 15 feet.
   b. Label one as the "Space Telescope Institute" (for the scientists) and one as "Outer Space" (for the space telescopes).
   c. Place another desk halfway between the two and label it as "Electromagnetic Waves" (for the data signal).

NESSP Mini-Mission: James Webb Space Telescope

Directions:

1. Instruct each student to find their group and to identify their role in the activity. Have students sit/stand in their assigned areas.

2. Once each group is in place, read the "Scripted Introduction" sheet aloud to the students. Explain that they will read the tasks for their positions once they open their folders.

3. Distribute the correct puzzle folders to each group and instruct students to leave the folder closed until told otherwise.

4. Set a timer for 90 minutes and instruct the students to begin by opening their folders and reading through their *About the Position* pages. Students can then start on their tasks outlined in these resources.

5. Monitor students as the activity progresses. Ensure students are collaborating and are not splitting the work between them:
    a. Each puzzle has valuable information on either JWST, the EM spectrum, or celestial bodies that each student in the group should learn in doing the puzzle.

6. Some questions you may be asked and how to address them:
    a. What am I supposed to be doing?
        i. "Please look through your sheet titled 'About the _____ Position.'"
    b. How do I get the attention of my data signal?
        i. "You can try a few things. First, politely call their name using an inside voice. If they do not respond, begin waving your hand to get their attention. If they still do not respond, raise your hand, and the teacher will check on the Data Signal to ensure they are participating with each group equally."
    c. What do I do if I finish my puzzles way before the other positions?
        i. If they're the Data Signal: "Jump back and forth between the Scientists and Telescopes to assist them wherever needed. You should ask before you physically touch any puzzle pieces."
        ii. If they're a Scientist or Telescope: "Discuss with your partner the information that you learned while completing the puzzles. Think about what you found most interesting and what you want to share with the group later."
    d. I don't know how to do a puzzle, and neither does my partner.
        i. If they have more puzzles: "Call over the data signal and ask for their help. If you still can't figure it out, move onto another puzzle and come back to this one."
        ii. If it's their last puzzle: "I'll help you by giving you a hint."

7. Once a group finishes the activity, they should call the instructor over with the launch codes written down. If the codes are correct, the instructor will reply, "You are a 'GO' for launch! Congratulations!"
    a. Explain that the resulting launch code is/was the most recent rescheduled date for launch (December 18th, 2021).

   b. *Note: All students in the group should be present at the game board when the code is read off.*

8. If an entire group finishes their activity within 90 minutes, give them the Quick Check Questions associated with their position to prepare them for the next activity portion.

Explain (18 min):

Preparation:

1. Hand out Quick Check Questions, 1 role-specific sheet per student

Directions:

1. Allow students 5 minutes to individually look over, think about, and write down answers to the four Quick Check questions associated with their position.
    a. If students finish early, encourage them to read through the other pages of the newspaper.

2. Gather students back in their large groups of five and give them time to complete 3 Minute Experts to share the information they learned about the EM spectrum, astronomy, or JWST.
    a. How to run 3 Minute Experts: Allow each position (space telescope, scientist, and data signal) 2 minutes to share the puzzles required to complete the activity. Then, allow that same position 1 minute to share all the **content-related** information they learned from the activity with their other groupmates. Once the three minutes are up, students switch so that the previous Experts become the Students and learn about the puzzles and information that the other students learned from the activity.
    b. Suggested rotation of Experts: space telescopes, scientists, data signal.
    c. Check-in on groups while performing this task to ensure they are sharing information relevant to the content learned for their position.
        i. Good information example: "I learned that different colors of light have different wavelengths, and that red has the longest wavelength while purple has the shortest."
        ii. Poor information example: "I learned that I like word searches."

Elaborate (8 min):

Preparation:

1. Bring the class back together as a whole for group discussion.

Directions:

1. Ask each position from each group to share something with the class that they learned **about the content** from another position in their group.
    a. Example: "I am a Scientist, and I learned from the Data Signal that the James Webb Space Telescope was named after a director of NASA - James Webb."
    b. If a student repeats something another student already mentioned, ask to share a different fact.
        i. If they can't come up with a new fact, tell them to discuss for 15 seconds in their group some information with their other positions in their group and then share again.

2. Ask the class, "How are the James Webb Space Telescope, the electromagnetic spectrum, and celestial bodies related to one another?"
    a. If students have not yet made the connection that JWST will use infrared to see into the first galaxies and into baby galaxies forming, then ask these questions:
        i. "What type of light does JWST see?"
        ii. "Where will JWST be sent to complete its missions?"
        iii. "What will JWST do on its mission?"
        iv. "What types of things will JWST see that previous telescopes could not?"

Evaluate (3 min):

Preparation:

None.

Directions:

1. Informal evaluation takes place throughout the activity.
    a. Continually ask students to elaborate on their ideas and work cooperatively with their teammates.

2. Have each student turn in their *Quick Check Questions* sheet from the Explain section for formal evaluation.

Extend (20 min):

Preparation:

1. Split the students into groups of two.
2. Print the Multiwavelength Bingo Game, 1 per group
    a. If you want to reuse the game, we recommend printing it on cardstock or glossy photo paper.
3. Cut out the game along the blue dotted lines or hand out scissors and have the students cut out the pieces before playing the game.

Directions:

1. Instruct students to find their assigned partner. Give each pair one Multiwavelength Bingo Board, 24 NASA chips, and one set of Multiwavelength Bingo Flashcards.

2. Share with the students: "When I call out a celestial body and the wavelength captured in the image, you will look at your flashcards and identify what the celestial body looks like. Then, look at your bingo board and identify if you have that body. If you do, place a NASA chip over the image. If you do not, do nothing and wait for the next card to be called out. When a group gets five in a row, they'll yell out 'BINGO!' and I will come to check their board."

3. Begin the game.
    a. Pull and call out celestial body cards. Keep these cards in a separate location from the remaining cards to cross-reference with student boards later.
    b. Ensure that students are taking turns handling the flashcards and placing the pieces on the board.
    c. When a student calls out "BINGO!", use the game pieces pulled to check their game board. If all of the covered spaces match cards that were pulled by the teacher, the students have won.

4. Once the game is done, ask students: "Which picture was your favorite? Why?" Allow students time (2 min) to discuss with their groups.
    a. Instruct them to identify the name of the celestial body and the type of wave (the wavelength) used to take the image.

5. Ask students: "What are the different types of waves we see in these images?" Allow students time (3 min) to discuss with their groups, and share out with the class.
    a. Check with each group to ensure that they hit at least: Radio, Infrared, Optical, Ultraviolet, and X-Ray. Mention that Gamma and Microwave waves exist as well, but are not featured in these images.
    b. May also want to clarify that 'composite' means that more than one type of light was used to construct the image.

6. Instruct students to turn their attention back to the Bingo Flashcards. Ask students: "Why is it that the same astronomical feature can look so different in pictures taken with different wavelengths?" Allow students time (2 min) to discuss.

Guidance For Adapting to Remote Learning

Major changes to the game setup:

1. Each student is sent a folder of prepared puzzles via mail, personal delivery, or pickup from the school in previous days.
    a. Can be placed in a sealed folder (like a manila folder) and have each student open on camera so that nobody could have looked through the puzzles prior to the activity.
2. Each role contains only one student (1 scientist, 1 space telescope, and 1 data signal) to create groups of 3.
3. The students are allotted 2 hours to complete the activity.
4. Each group is assigned to a breakout room where they will conduct their game.
5. Each student must have access to a working video camera connected to their online communication method (i.e. Zoom, Microsoft Teams, etc.)

Major changes to the gameplay:

1. Communication should be collaborative among all three roles.
    a. I.e. The scientist can communicate directly with the telescopes and vice versa.

Major changes to evaluation:

1. Each student will need to take photos of each puzzle once completed for proof of completion.
    a. These images will be turned in with the *Quick Check* questions.
2. The instructor will pop into each breakout room frequently to assist with puzzles that students are struggling with.

Lesson 2: Telescopes and Optics

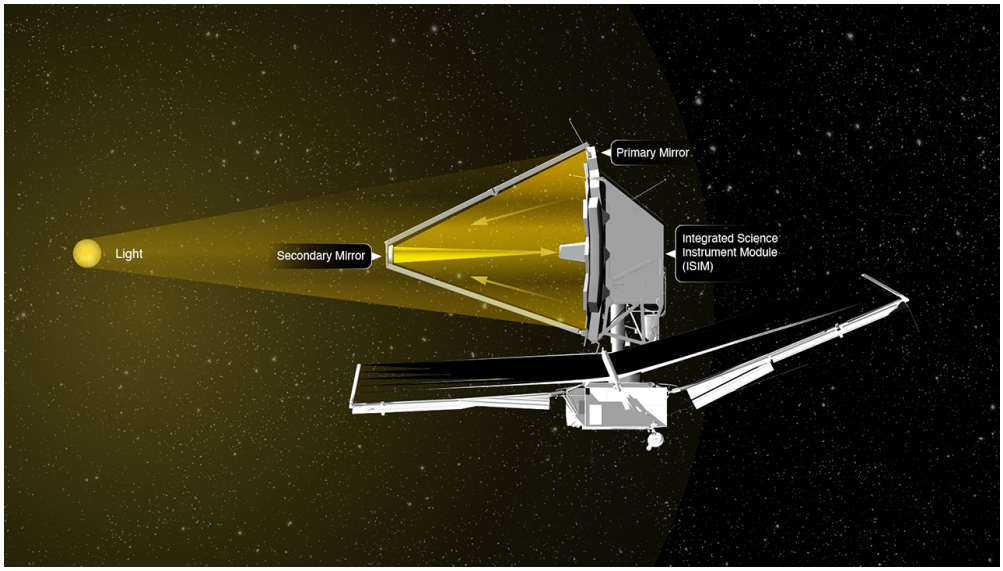


Image Credit: Space Telescope Institute

Lesson Level Question:

How do telescopes collect and magnify light, allowing us to observe distant objects?

Lesson Summary:

Students will learn about refraction or how light bends at the boundary between air and water or air and glass. Students will learn how lenses and mirrors collect, focus, and redirect light in the three main types of telescopes. They will compare the magnification and light collecting ability of a Celestron FirstScope Telescope, Hubble Space Telescope, and the James Webb Space Telescope. Finally, students will be able to observe objects in the classroom using the small desktop telescope.

Materials:

- Clear glass and water
- Calculators
- Educational hand-held lenses (available from NESSP)
- Celestron 2120 FirstScope Desktop Telescope (available from NESSP)
- Telescope Sorting Game Cards
- Telescope Description Sheet
- Telescope Magnification Worksheet, Telescope Magnification Worksheet (Google Docs)
- Collecting Light Worksheet, Collecting Light Worksheet (Google Docs)
- Telescope Observation Worksheet, Telescope Observation Worksheet (Google Docs)
- Lens Exploration Worksheet, Lens Exploration Worksheet (Google Docs)
- Telescope and Optics Slide Deck

Background:

This lesson introduces students to the basics of refraction (the bending of light in materials like water and glass) and how telescopes use refraction to focus and magnify light from distant objects. Light bends at the boundary of air and glass or air and water because the speed at light travels (slightly) changes. The best way to explain it to young students is to use an analogy like the marching band one provided here. However, you do not need to explain why light bends in this lesson.

Lenses in telescopes bend light to focus it on a smaller area. During the Explore portion of this lesson, students will observe that lenses change an image's size, orientation, and brightness. Focusing more light into a camera allows telescopes to observe dim objects that are far away.

Mirrors also change the direction of light. Light will reflect off the surface of a mirror at the same angle that it hits the mirror. Curved mirrors focus light similar to a lens. Telescopes often use mirrors instead of the lens because large mirrors are cheaper and easier to produce. They are also lighter, which is essential when launching the mirror into space.

There are two main types of telescopes: refractors and reflectors. Refractors employee lenses only. Early telescopes (like the one used by Galileo) were refractor telescopes. Today refractors are usually smaller telescopes (including binoculars). Reflector telescopes use a combination of mirrors and lenses. Reflectors use curved and flat mirrors to gather, focus, and change the direction of light. This lesson describes the third type of telescope (a compound). This type of telescope is a variation of the reflector telescope. Students will learn that Hubble and James Webb Space Telescopes are more complex versions of a compound telescope.

Students will compare the focal length and “light-collecting area” (mirror size) of Hubble, JWST, and a Celestron FirstScope Telescope. Larger lenses and mirrors usually have large focal lengths; therefore, a large focal length means more light is collected, and dimmer objects can be seen. Inside Hubble and the JWST, mirrors bounce light back and forth so that the telescope body can be a fraction of the size of the focal length.

The combination of how the primary mirror (the one initially gathering light) and the eyepiece (or lens used to focus light on the camera) bends determines the magnification of the image. In telescopes, light is bent in such a way that objects appear larger. Students will directly observe during the Evaluate portion of the activity!

Happy observing!

Engage (10 min):

Credit: Institute of Physics

Preparation:

1. Gather two glasses. One should contain water that will be poured into the other. At least one of the glasses must be clear.
2. Draw two arrows on a sheet of paper and prop the paper behind the clear empty clear glass as shown in the image above. During the demonstration, you will move the glass, and the paper will be stationary.
3. If you want, you can test the demo and find the appropriate distance to place the glass so that the bottom arrow is reversed and about the same size as the upper arrow. This is an excellent location to move the glass to and keep it at when discussing the demo.
4. If possible, project the demo to the whole class. If that is not possible, have the students gather around the demonstration table or do the demonstration several times.

Directions:

1. Show students the empty glass with the arrows behind it. Ask students to put one hand above the other and point their thumbs in the direction of the arrows.

2. Ask the students what they think will happen when you fill the glass halfway with water. Solicit at least 3 ideas.

3. Tell the students you are about to fill the glass with water and to use their thumbs to note any changes in the arrows. Fill the glass halfway with water (make sure it is sufficiently close to the paper so that the arrow does not flip directions). Grown, "Shucks! I guess nothing happens!" Think for a moment, and then slide the glass away from the paper to the mark where the arrow flips.

4. Have the students do a think-pair-share:
   Think: think for 2 minutes about why the arrow flipped
   Pair: discuss and share your ideas with a partner for 2 minutes
   Share: have one partner prepare to share their ideas with the class

5. Pick several students to share their ideas but do not confirm the correct answer or explain the demonstration. Instead, say, "Let's see what more we can learn by exploring what happens to light when it passes through glass."

Explore (15 min):

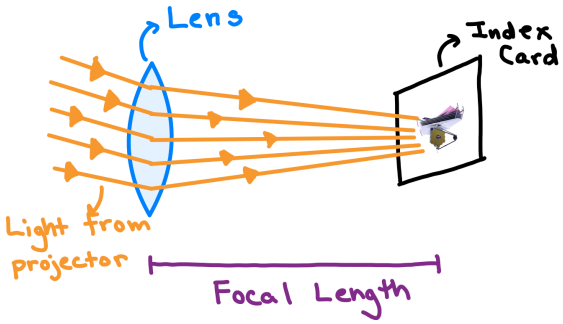
Preparation:

1. Split the glass into groups of 2-4 students
2. Hand out at least one converging lens to each group of students. Additional lenses can be converging or diverging. (Note: Converging lenses are thicker in the middle than at the edges.)
3. Hand out note cards, one per group
4. Hand out rulers, one per group
5. Print out the Lens Exploration Worksheet, one per student.
6. Prepare to project the image of the JWST in the Telescope and Optics Slide Deck

Directions:

1. Give the students about 5 minutes to explore the lenses and to document findings on the Lense Exploration Worksheet. Make sure the students draw lenses from the side of the table. Students should observe and document how objects (like a pencil) look through the lens when the objects only a few cm from the lens and further away (> 5 cm). Walk around the classroom and ask students to describe their observations. For a converging lens, students should notice that the image is right side up when the lens is close and upside down when the lens is far away.

2. Ask the students to pick out the converging lens or a lens that is thicker in the middle than at the edges. Project the image of the James Webb Space Telescope in front of the classroom. Ask students to place the index card behind the lens, so the light from the projection screen passes through the lens and shines on the index card. Tell the students to move the index card until they see a clear image of James Webb on the card. If done correctly, the image should be upside-down and bright.



3. Ask the students,
    a. “What do you notice about the image on the card? Is it right side up or upside down?“
    b. “How does the size of the image change if you move the card forwards and backward?”

4. Say, “Make the image as bright and clear as possible.” Instruct them to use the ruler to measure the distance between the center of the lens and the index card. This distance is called the focal length of the lens. Tell the students to write it on their Lens Exploration Worksheet.

Explain (15 min):

Preparation:

1. Split the students up into groups of 3 or 4.
2. Prepare to present the Telescope and Optics Slides
3. Hand out the Telescope Sorting Cards, one per group. Cut the cards along the solid lines or hand out scissors so that students can cut them out.

Directions:

1. Flip between Slides 3 and 4 in Telescope and Optics Slide deck to demonstrate how light bends when it moves from air into glass. Tell the students that the bending of light allows lenses to focus light from an object and magnify it onto a different surface. This is what they observed during the Exploration portion of the activity.

2. Show students Slide 5 and say, "Imagine viewing the glass of water in the demo from above. Each line represents the path of light from either end of the arrow." Carefully trace the rays of light as they move through the glass to show that they flipped or inverted due to the bending of the light.

3. Show Slide 6, titled "Focal Length." Trace and explain that light passing through the glass comes together and focuses at a single point. The distance from the lens to the point is known as the focal length.

4. Show Slide 7 and ask the students, "How is the way light interacts with a curved mirror similar to the lens?" They should note that light is focused towards a single point. Tell the students, "Telescopes often use curved mirrors like this one to collect and focus light rather than lenses because they are lighter, less fragile, and easier to make."

5. Hand out the three telescope cards from Telescope Sorting Cards. Tell the students that the cards depict the path of light in three different types of telescopes. Have students trace the path of each of the three light rays shown with a marker or pen.

6. Hand out all of the telescope cards except the ones with JWST and Hubble. Have the students sort the telescopes by placing them under one of the previous three telescope cards. Consider giving a small prize to the group who gets the most correct. (Some cards will be difficult to sort.)

7. Hand out the Hubble and JWST cards and ask the students to sort them. After, reveal that both telescopes compound telescopes. Have the students do a think-pair-share:

   Think: think for 2 minutes about why they are compound reflectors rather than refractors
   Pair: discuss and share your ideas with a partner for 2 minutes
   Share: have one partner prepare to share their ideas with the class

   Choose several groups to explain and, if necessary, give hints. Students should conclude that big mirrors are lighter than big lenses and that the bouncing of light inside reflecting telescopes allows them to have focal lengths that are larger than the length of the telescope.

Elaborate (25 min):

Preparation:

1. Print out enough copies for each student to have the Telescope Description Sheet, the Telescope Magnification Worksheet, and the Collecting Light Worksheet
2. Prepare to present the Telescope and Optics Slides
3. Hand out one set of gold star stickers (or similar) to students
4. Make sure each student has access to a calculator
5. Place a Celestron FirstScope Telescope at the front of the class (optional)

Directions:

1. Show Slide 8 in the Telescope and Optics slide deck. Tell students that they will compare the capabilities of the Celestron FirstScope Telescope to the capabilities of Hubble and JWST. Hand out the "Telescope Description Sheet" and note that it lists important information for each telescope that they will need to complete the activity.

2. Hand out the Telescope Description Sheet and the Telescope Magnification Worksheet. Tell the students, "Use the information on the Telescope Description Sheet and the magnification equation to complete the table on the Magnification Worksheet." Walk around the classroom to observe the work as students make the calculation, providing help as needed.

3. Show students Slide 12 and ask, "Which bucket will collect more water in one minute?" Next, show Slide 13 and ask, "Which mirror will collect more light in one second?" The students should note that bigger mirrors collect (or intercept) more light from an object.

4. Hand out the Collecting Light Worksheet and the gold stickers. Tell the students that the circle on the worksheet is the same size as the lens in the Celestron FirstScope Telescope. Instruct, "Fit as many gold stickers as you can in the circle without overlapping them. When done, count the stickers and write down the number on the table on the worksheet."

5. Describe how to calculate the area of a circle using the formula. Calculate the collecting area of the Celestron FirstScope Telescope in front of the class as an example (if needed). Tell the students to use the information from the Telescope Description Sheet to calculate the light-collecting area for Hubble and the James Webb Space Telescope.

6. To introduce proportional reasoning, ask, "If the mirror in the desktop telescope was 2x as large, how many stars could you fit on it?" "What if it was 3x as large?" "How much larger is the mirror on Hubble compared to the Celestron telescope?" Demonstrate this calculation in front of the class and then ask, "Based on this can you calculate how many gold stars would fit on the mirrors of Hubble and James Webb?" This calculation might be tricky for the students. Walk around, observe their work, and help as needed.

7. Say, "The gold stars represent the amount of light from a distant object hitting each mirror in one minute. Many more stars fit on the JWST mirror, and this means JWST can collect A LOT of light, allowing it to produce bright images from dim and distant objects." Display Slide 11 again to emphasize the difference in mirror size for each telescope.

Evaluate (30 min):

Preparation:

1. Prepare to present the Telescope and Optics Slides.
2. Print out images and tape them on the walls around the room. Options at several scales are provided in the Telescope and Optics Slides. Choose one that is appropriate given the size of the room. You can also place or use a 3D object in the room for the students to observe. It is best if it has some detail (like text or small graphics) that can only be seen under magnification.
3. Hand out the Telescope Observation Worksheet, one per student. If you plan to have students observe multiple objects, print out multiple copies of the last page or "Observation Sheet".
4. Split students into groups of 3-4 and provide each with a Celestron FirstScope Telescope. Keep the eyepieces separate and hand them out when it is time to observe.

Directions:

1. Tell the students, "There are 360 degrees in a circle". Use your arms to depict a vertical circle around the room. Tell the students, "Astronomers describe how big something looks in the sky by measuring its width in degrees. This width is called the angular diameter."

2. Show students Slide 11 in the Telescope and Optics Slide deck and ask them to extend their arms and examine the width of their pinky. Tell them an object with the same width has an angular diameter of about 1°. Ask, "How wide do you think the moon is?" Solicit several answers. Click on the next slide (or start the animation) to show that the moon is only 0.5° wide. Ask the students to find something in the room that is about as wide as the moon looks in the night sky.

3. Show Slide 12. Say, "Find something in the room that is about 5° wide. " Then "How about 8°?"

4. Show students slide 18. Explain that this slide indicates the field of view of the JWST. Its main instruments will take pictures that are about 0.05° or 1/10th the size of the moon in the night sky.

5. Hand out the Telescope Observation Worksheet. Direct the students' attention towards one of the objects you want them to observe in the room and ask the students to use a hand at the end of an outstretched arm to estimate the angular size. Tell the students to use this information to complete the first page of the worksheet. If students completed the Telescope Magnification Worksheet on a different day, they might need to be reminded or told that the Celestron FirstScope Telescope magnification factor is 15x.

6. Point to the object(s) you want the students to observe in the room. Tell students to write a description of the object on the worksheet based on their eye observations.

7. Show the students how to remove each of the protective covers (if they haven't already). Show the students Slide 15 and point out the different parts of the telescope. Leave this slide up as you instruct them on how to point and focus the telescope.

8. Hand out the 20 mm eyepiece and show the students how to insert the eyepiece into the "Eye" slot on the telescope and tighten the screws.

9. Demonstrate how to align the telescope, first by rotating the "Optical Tube" horizontally towards the target. Next, vertically rotate the "Optical Tube" until it is pointed near the target. Tell the students to tighten the "Lock Nut" but not so much that they cannot move the telescope and make small adjustments later.

10. Have one student in each group focus the telescope by looking through the eyepiece and slowly turning the "Focus Knob." Tell the students that the focus knob moves the lens in the eyepiece to focus the light onto the light-sensing portion of their eye. Once the object is in focus, have the student slowly move the "Optical Tube" right-to-left and up-and-down until they find the object. This will take some time! Once the object is found, tell the student to tighten the "Lock Nut" further so that the telescope stays pointed towards the object without being held.

11. The first student should observe the object through the telescope and write down additional details about the object on the Observation Worksheet. When they are done, another student in the group can take over. Depending on time, you may want to allow each student to go through the whole process of aligning the telescope or have each focus the telescope but maintain its current alignment.

12. Walk around the classroom as students observe. If you want, you can tell them that the field of view of their Celestron telescope is 1.7°. Ask them to describe whether this is consistent with what they observe. They should compare their observations of the angular diameter of each object to the fraction of view it takes up when observed through the eyepiece.

13. If you have extra time, allow students to observe other objects throughout the classroom. Tell them a good scientist takes notes, so they should fill out an Observation Sheet for each object they choose to observe.

Extend:

Preparation:
None.

Directions:

1. The best way to extend this activity is to allow students to view objects in the night sky.
2. We recommend you have students use the Celestron FirstScope to observe the moon using both the 20 mm (15x magnification) and the 4 mm (75x magnification) eyepieces. It is particularly interesting to look at shadows, the edge of the disk, and the boundary between light and dark. The observation sheet from the Evaluate can be used for Moon observations as well.
3. The FirstScope can also be used to observe far-away objects during the day. If you use the telescope outside during the daytime, warn students repeatedly not to look at the Sun with the telescope.

Guidance for adapting to remote learning:

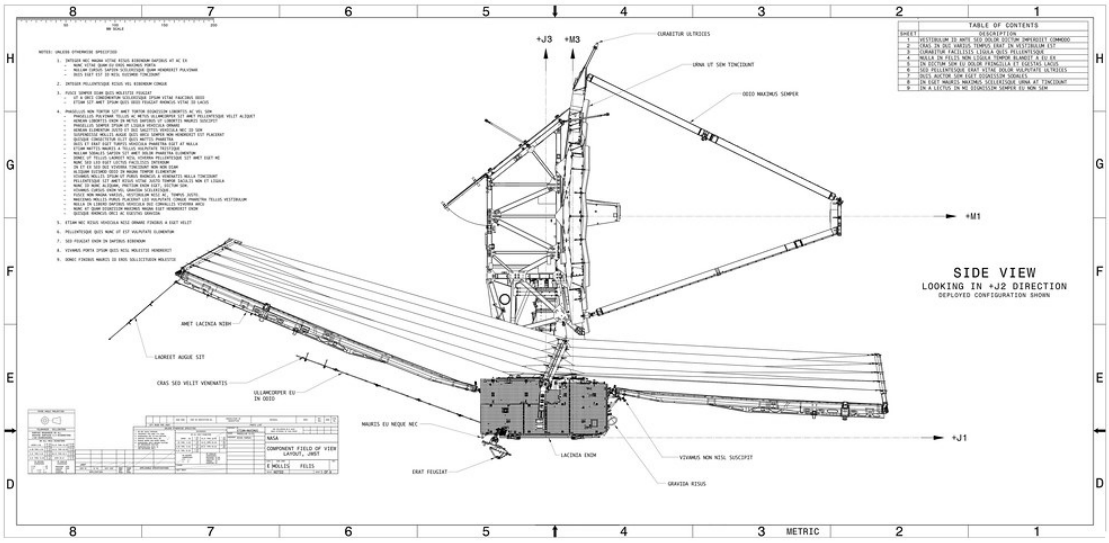
Several portions of this lesson can be adapted to remote learning. With careful placement and some practice it is possible to do the Engage demo over Zoom. You can utilize online simulations such as Phet Bending Light simulation (https://phet.colorado.edu/en/simulations/bending-light) to explain the demo and demonstrate refraction.

Images from the telescope sorting activity can be cropped so that students can sort them on a slide or a word document on a computer, either individually or in groups in a breakout room.

The Magnification and Collecting Light Worksheets can also be completed individually at home or in groups in a breakout room. Google Docs versions of these worksheets are provided on the first page of the lesson.

Finally, if you cannot give students access to a Celestron FirstScope to complete the final activity, you could ask if they have binoculars or another telescope at home. In some cases, the students may be able to look up the magnification for their own optical devices and complete the activity in a way that allows them to compare the results to the capabilities of Hubble or JWST.

Lesson 3: Build Your Own Telescope



Credit: NASA/JPL

Lesson Level Question:

How does the design of your telescope allow it to function correctly and effectively while gathering its images?

Lesson Summary:

Students will use the information they have gathered about the James Webb Space Telescope and other space telescopes to design their space telescope. Students will justify their design choices and critique one another's designs in a formal setting. Then, each student/group will consider the critiques and make adjustments to their designs.

Materials:

- BYO Telescope Worksheet - Concept and Blueprint, JWST BYO Telescope Worksheet - Concept and Blueprint (Google Docs)
- BYO Telescope Lecture slides
- Laptops/computers with access to the internet
- Miniature Telescope for visual aid (OPTIONAL)
- Household building materials such as paper towel tubes, boxes, tin cans, mirrors / mini reflectors (OPTIONAL EXTEND)

Background:

In the previous lesson, students learned how telescopes "work" or how they use lenses and mirrors to gather, focus and magnify light. In this lesson, students will explore the most important components of a space telescope and design their own.

The advantage of putting a telescope in space is that light is not absorbed or distorted by Earth's dense atmosphere. However, solving that problem introduces many others. Space telescopes need special equipment to keep them safe during launch, maintain their orbit, point them towards the object they are observing, provide power, keep their science instruments at the correct temperature, etc.

Students will learn that JWST has the usual components of a ground-based observatory, including a large primary mirror (made of 18 segmented hexagons) and a secondary mirror. The optical equipment is supported by the backplane, which sits on top of JWST's large sun shield. JWST has no optical tube. There is no dust or dirt to worry about in space, and the sun shield blocks the sunlight.

The JWST has four science instruments. Three cameras take pictures in different parts of the infrared spectrum, and one spectrograph splits light up into its component wavelengths. Another purpose of the multi-layer sun shield's primary purpose is to prevent JWST from warming up in the sunshine. A warm JWST would emit infrared light and would ruin infrared images of far-away objects. All of the science instruments are housed in the Science Instrument Module or SIM.

The other side of the sun shield houses the portions of the telescope that keep it working. This includes a solar array for power and a spacecraft bus that houses the computer and steering mechanism (spinning wheels called reaction wheels). A star tracker also looks for well-known stars and tells the computer which way the telescope is pointing. Finally, there is an antenna to send all that data back to Earth.

Students will discover that many of the space telescopes have similar components (cameras, star trackers, reaction wheels). In some cases, their sun shades are tubes, or they may not have sunshades at all. Depending on what wavelengths of light they observe, their optical components may be very different.

Students should be allowed to create whatever telescope they choose; however, this lesson intends to have students use communication and the iterations to improve their design. Launching a telescope into space above the atmosphere enables some powerful science; however, it also comes with complexity and risk. JWST will be the most complex telescope NASA has ever launched into space, and the engineers and scientists who designed it have gone through many iterations to get it just right.

Engage (20 min):

Preparation:

1. James Webb Space Telescope: An Overview video
2. Computer with access to Youtube.com
3. Large screen/projector for sharing the screen with class
4. Display miniature telescope for a visual aide
5. JWST BYO Telescope Lecture

Directions:

1. Show students James Webb Space Telescope: An Overview

2. When the video is complete, ask students, "What were some of the parts of the telescope they mentioned in the video?" Take some responses from the class.

3. Rewind to 1:31 and pause the video on JWST. Alternatively, show this image to the class. Ask students, "What stood out to you about the different parts of the James Webb Space Telescope? What do you think the purposes of those parts are?" Allow students to share with their partners for 1 minute, then share out with the class for 3 minutes.

4. Ask students, "How does JWST look similar to and different from the telescopes we use on earth?" Allow students to share with their partners for 1 minute, then share out with the class for 3 minutes.
    a. Have a miniature telescope available to show students what an earth telescope looks like. (OPTIONAL)

5. Share with students that we will be learning about the important parts of space telescopes, and we will discuss what sorts of things are important to think about in designing our own telescopes.

6. Briefly guide students through the JWST BYO Telescope Lecture slides (OPTIONAL - max of 10 min).

Explore (45 min):

Preparation:

1. Computers/laptops with internet access: one per student or pair of students
2. Scope it Out activity
3. Print and distribute JWST BYO Telescope Worksheet - Concept and Blueprint

Directions:

1. Ask each student to obtain a computer/device with internet capabilities to do some preliminary research on different telescopes (approx 15-20 min).
    a. First, send students to the Scope it Out activity to learn more about the parts of a telescope.
    b. With any remaining time, direct students to the following resources to learn more about the design of different space telescopes.
        c. Kepler design
            i. About Kepler
        d. James Webb design
            i. About James Webb
        e. Hubble design
            i. About Hubble
        f. Spitzer design
            i. About Spitzer
        g. Remind students that if they look outside of the provided resources to look for reputable sources, such as NASA.

2. Ask students to put computers away / off to the side. Allow students to think-pair-share:
    Think: think for 2 minutes about their own design (can write ideas down if desired)
    Pair: discuss for 2 minutes each (total 4 min) with their partner what their design ideas are.
    Share: share for 1 minute each (total 4 min) with one other pair what their design ideas are.

3. Ask students to obtain a pencil and pass out the JWST BYO Telescope Worksheet - Concept and Blueprint. Allow students time (20 min) to write out their design concept in words (in the boxes) and draw a blueprint (in the circle) for their model.
    a. Encourage students to think about topics beyond what is provided in the boxes. Can ask:
        i. "How will it get to space?"
        ii. "How can you make it lighter?"
        iii. "How will it focus an image it takes? Like a camera focuses on a subject?"
        iv. "How does it transmit the images back to earth?"
    b. Note: Blueprint should include labeled parts of the telescope.

Explain (25 min):

Preparation:

1. Obtain sticky notes - enough for approximately 20 sticky notes per student

Directions:

There are two options for having students share and critique the telescopes.

Option 1: Gallery Walk

1. Ask students to put down pencils and stack their concepts/blueprints in a pile in the middle of their desk of four. Ask one student to gather all of the piles.
2. Place sheets on desks or pinned on walls around the room with blueprint-side-up while playing An Introduction to the JWST (3:43 min).
3. Once the video is finished, ask one student from each table to grab a sticky notepad for their group. Ask students to each take approximately 20 post-its from the pile.
4. When each student has sticky notes, and the papers are spread out across the room, ask students to get up and begin viewing the different telescopes.
5. Each time a student has a critique, they write it on a sticky note and stick it to the table/wall underneath the telescope blueprint.
    a. **The instructor should monitor critiques that are being left to ensure students are being respectful and are meeting the standards expected of a student effectively applying the Engineering Design Process.**
    b. If there is concern that students will not be able to critique respectfully, review the JWST BYO Telescope Lecture slides.
    c. When walking the gallery, students should not touch the blueprints at all and should not turn them over to reveal the name of the creator.
6. Students return to their seats once finished critiquing and begin brainstorming potential changes for their own telescopes until everyone is done with the gallery walk.

Option 2: Small Group Critique

1. Ask students to put down pencils and pass their concepts/blueprints to the person on their right.
2. Ask students to begin reading the design concept while the instructor passes out sticky notes to each table.
3. When students finish reading the design concept, instruct them to grab a few sticky notes and begin reviewing the telescope design blueprint on the back.
4. Each time a student has a critique, they write it on the sticky note and stick it to the edge of the telescope blueprint (so it is not covering the image or labels).
    a. **The instructor should monitor critiques that are being left to ensure students are being respectful and are meeting the standards expected of a student effectively applying the Engineering Design Process.**
    b. If there is concern that students will not be able to critique respectfully, review the JWST BYO Telescope Lecture slides.

Return the telescope designs to the creator and ask students to read over critiques left by their peers.

Elaborate (20 min):

Preparation:
None.

Directions:

1. Take the time (10 min) to discuss the following questions as a class:
    a. "What are some of the most important features for a telescope to have?"
        i. Write responses on the board / for everyone to see.
        ii. The instructor may need to guide the students towards specific features.
    b. "What are some things we may have forgotten in our original designs that we are going to add into our revised design?"
        i. Focus students on using proper vocabulary.
    c. "What was one thing you saw on another student's telescope that you believe was a great addition?"
        i. Have students explain the feature and its purpose. Then explain why that purpose is important to a space telescope.
            1. I.e., "My partner decided to add solar panels which gather light from the sun and turn it into electricity. This is important because telescopes have equipment that needs electricity to work, and there aren't any telescope charging cords in space."

2. Allow students time (10 min) to make adjustments to their telescope designs based upon the suggestions/critiques left by their peers.
    a. Encourage students to think beyond their peer's critiques and think about more ways that their telescope can improve based on features they saw in other's telescopes.

Evaluate (20 min):

Preparation:

None.

Directions:

1. Students share their final design blueprints with their table groups (or partner pair they shared with before), and discuss their changes to their telescope design and why.
    a. Instructors should walk from group to group and listen to most of the individuals share their improvements.
        i. Focus on guiding students to use proper vocabulary and explain why the change to the design was an improvement.

2. Have each group identify AS A GROUP which telescope meets the following requirements best:
    a. Body to hold telescope parts together
    b. Power source
    c. Viewing tool
    d. Magnification (reflecting or refracting telescope)
    e. Stabilization
    f. Insulation
    g. Ability to fit into a rocket
    h. Other: _____

3. Ask students to write three to four sentences as to why they chose this telescope over the others.
    a. Ensure students use reasoning in their answers and avoid circular answers such as, “It’s better because it’s just the best.”

4. Ask each group to bring up their chosen telescope to the board and share their reasoning for choosing this telescope.

5. Each student turns in their telescope designs, the sticky note critiques, and their sentences explaining why they chose the telescope they did.

Extend (60 min):

Preparation:

1. Collect household building materials such as:
    a. Paper towel tubes
    b. Boxes
    c. Tin cans
    d. Mirrors / mini reflectors
    e. Plastic utensils
    f. Cardboard

Directions:

1. Using resources found from around the classroom/house, allow students time (40 min) to build a model of their telescopes.

2. If the instructor wishes to reduce the time for this section, they can have each group of students build one single model of the telescope they chose in the Evaluate section.

3. Have students share out their telescopes by either:
    a. Asking students to place telescopes around the room for students to view over the coming days/weeks.
    b. Asking each group to bring up their chosen telescope to the board and share their reasoning for choosing this telescope.

Guidance for adapting this lesson to remote learning:

If students lack access to a printer, the design concept/blueprint can be completed on a blank piece of paper. Student discussion can take place on Zoom, where small group discussions take place in breakout rooms. When it comes time to share the telescopes and complete the critiques, the other students can make notes while one creator is sharing their design and then share the critiques with the student in a private message or through verbal discussion.

Lesson 4: Science Goal Scavenger Hunt

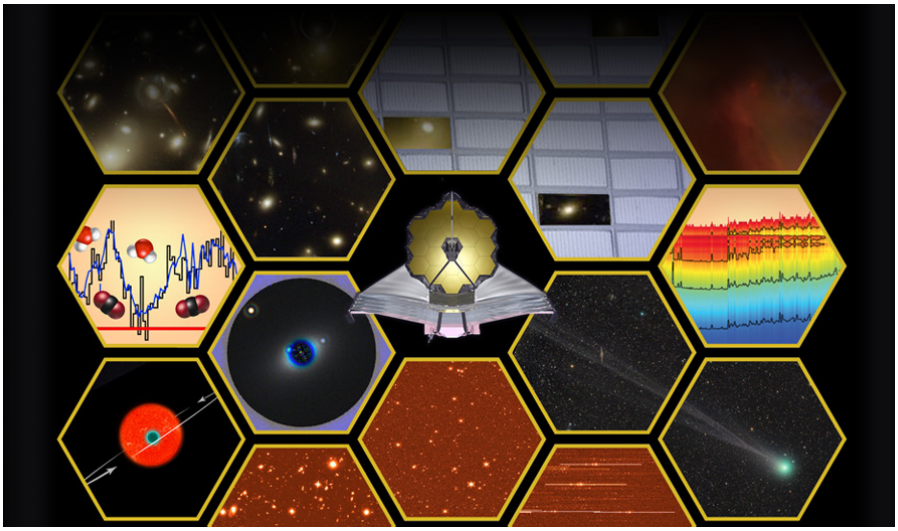


Image Credit: NASA/JPL

Lesson Level Question: How will the James Webb telescope use its observation to achieve its science goals?

Lesson Summary: Students will explore Worldwide Telescope (WWT) and download images that the James Webb Space Telescope (JWST) might observe to achieve the science goals of its future missions. The goal will be for students to become familiar with the science goals of JWST during the Engage portion of the activity. In the Explore portion, students will hunt down images that might be useful for addressing one of 18 key science questions JWST is targeting. By the end of this lesson, students will present a slide to the class to explain what the object they selected is and why observing it will address one of the key science goals of JWST.

Materials:

- Laptops with internet access
- WWT Scavenger Hunt Slides
- WWT Scavenger Hunt Student Slides
- JWST Scavenger Hunt Worksheet, JWST Scavenger Hunt Worksheet (Google Docs)
- JWST WWT Tour Outline, JWST Tour Outline (Google Docs)
- Optional: WWT Program Download (PC Only)

Background:

You and your students have learned a lot about the telescope itself; now we focus back on what the telescope will do once it is launched into space and unfurls its large mirror and even larger sunshield. Every NASA mission starts with science and JWST is designed to address science questions covering four different themes or areas: Early Universe, Galaxies Over Time, Star Life Cycle, and Other Worlds. These science themes are broad, and it is OK if you or your students do not understand every aspect of them. After all, JWST hasn't launched yet. This background will hint at what objects your students should search for in this lesson (and JWST will eventually observe).

One of the most powerful aspects of the JWST is its ability to look back in time. As discussed in previous lessons, the large mirror of JWST means it can collect the dim light of faraway objects. However, JSWT has another trick. It is observing infrared light. Visible light was emitted by the earliest stars and galaxies in our universe, just like it is today. The universe has expanded in all directions, like muffins baking in the oven, over the last 13 billion years. As the universe expands, light waves traveling through space are also stretched. That means some of that ancient *visible* light has a longer wavelength and now can be observed in the infrared. James Webb will search for red-shifted ancient light from these distant galaxies to address questions about the early universe.

JWST is also designed to study the properties and evolution of galaxies both in the early universe and today. Hubble has shown us that the very earliest galaxies have different forms and shapes of most recent ones, and JWST will be able to observe even older galaxies. JWST will also be able to observe the properties of galaxies today including what they are made of (using its spectrometer) and how that material is distributed throughout the galaxy. It will also observe how large black holes at the center of galaxies affect their evolution and what happens when galaxies collide to form new larger galaxies.

Another benefit of observing in the infrared is its ability to penetrate the dust throughout the galaxy. While dusty nebulae (like the Pillars of Creation in the Eagle Nebula) make for beautiful pictures, the dust blocks visible light emitted when the dusk becomes unstable and collapses to make a hot young star. When telescopes observe the same nebula in the infrared, they are able to see through the dust and discover what is happening inside. This view will help scientists study the very earliest stages of star formation, including the formation of planetary disks.

JWST is also interested in more down to Earth topics, including the properties and formation of planets in our solar system and beyond. Its studies of protoplanetary disks will help us understand the early stage of planetary formation. Its spectrometer can be used to split light into component wavelengths, revealing the fingerprint-like spectral signature of the atoms and molecules in the atmospheres of solar system objects and some exoplanets. It's powerful optics can also be used to observe some of the smallest (and therefore dimmist) objects in our solar system like asteroids, comments, and the dwarf planet Pluto.

Engage (10 min):

Preparation:

1. Prepare to show a YouTube video to the full class.

Directions:

1. Ask students, "What type of objects do you think the James Webb Telescope will take images of? What type of science questions do you think it will investigate?"
    a. Take responses from the group. If nobody has anything to share, ask students, "Who has heard of the Hubble Space Telescope? What type of images did Hubble take? How is JWST similar to or different from Hubble?"
    b. Note, if you did not do any of the previous lessons, you may want to introduce the James Webb Telescope first by doing the Engage from Lesson 1.

2. Explain to students, "We are going to watch a video about the science goals of the JWST. Try to remember or take notes on the science goals of JWST and what type of objects it might investigate." Show the students this video: https://www.youtube.com/watch?v=rlz2nNfknww

3. Ask students again, "Now, based on what you observed in the video, what type of objects do you think the James Webb Telescope will take images of? What type of science questions do you think it will investigate?"
    a. Take open responses from the group or split the students into groups of 2 or 3 and have them think-pair-share their ideas:
    Think: "What is one science goal of JWST? What object might it take an image of?" (2 minutes)
    Pair: Share your ideas with your partner or group (2 minutes)
    Share: Be prepared to share your group's ideas with the class (1 minute)

Explore (50 min):

Preparation:

1. Split students into groups. There are 18 "clues" for the scavenger hunt, so you may want 6 or 9 groups per class. If you have six groups, each group will investigate 3 clues, and if you have 9, each group will investigate 2 clues.
2. Have access to computers - one per student or group of students
3. Have access to the WWT web client or (optional) download WWT on each computer (PC only).
4. Copy the WWT Scavenger Hunt Student Slides, change the permission so that students can edit the slides, and prepare to share the slides with students by copying or distributing the Share link.
5. Copy the WWT Scavenger Hunt Slides and include the link to the "Student Slides" on Slide 14. Prepare to share the slides with students by copying or distributing the Share link. Students do not need to edit these slides so *do not* edit the permissions.
6. Print out JWST Scavenger Hunt Worksheets, 18 total (one per Mission Objective)

Directions:

1. Pull up the web client of Worldwide Telescope (WWT) on a screen that all students can see.
    a. Explain: "WWT is a program that allows the user to look around space and zoom in on celestial bodies. The images located in WWT are real images taken by telescopes, observatories, and other sources."
    b. Show students that you can find images by opening collections, searching, or panning across the sky (see slides for details).
        i. Collections are found at the top panel
        ii. To Search: open the search tap at the very top of the screen.

2. Have each student or pair of students log into a computer with internet capabilities and have them open the WWT web client.
    a. Tell students to go through the short tour when they open WWT.
    b. Allow students time (5-10 min) to explore WWT.

3. Go through the slides "Getting Familiar with WWT" slides from the slideshow while the students follow along. Ask the students to give you a sign (thumbs up) when they have completed the task.

4. Ask students to stop interacting with their computers. Have them turn laptop screens away from them or flip keyboards upside down.

5. Hand out JWST Scavenger Hunt Worksheet, 1 per clue per group (if you have 6 groups each group will get three sheets, if you have 9 groups each will get 2).

6. Assign each student to a Mission Objective (found in the WWT Scavenger Hunt Slides).
    a. This can be done via random selection (have each student choose or draw a number), or this can be done by assignment (having each student assigned a mission by the instructor).
    b. The slides are linked, click on each hexagon to reveal the Mission Objective.
    c. Have the students write their Mission Objective number on their worksheets
    d. Share the link to the WWT Scavenger Hunt Slides with the students so that they can review their Mission Objective and the "Investigate Material".

7. Show students the link to the WWT Scavenger Hunt Student Slides. This should be replaced with a link that is specific to your class! Open the link and show students how to replace the mission clue hexagon with a hexagon that shows their image.
    a. Right-click on the hexagon with the number that corresponds to their mission objective.
    b. Select the dropdown from "Replace image" and choose "Upload from computer" from the toolbar.
    c. Go to the location where the image was saved and select the image.
    d. The image should automatically update to be that student's image in the hexagonal shape.

    Tell them that every image must be unique! If another group has already used an image, then their group will have to find a new one.

8. Allow students time (20 min) to investigate their clue and search in WWT to find a specific celestial body that will fulfill their mission and correspond to the type of celestial body they identified in the first question. Ask students to fill out question five on the worksheet with the appropriate information.
    a. As students search through WWT, check-in with each group and ask them to explain their choice of celestial body.
        i. If students have not identified a type of celestial body that would fulfill their mission objective, guide them to a more appropriate type of celestial body.
    b. When students find the image they would like to use have students right click on the image or use a screen hot to "grab" it, and save it to their device under a name that is easy to identify and their mission objective number (i.e. "Helix Nebula Objective 2").
    c. Tell students to do a little more research on each object (either using the information in WWT or by googling the name) and have them address the prompts on the worksheet. Don't let them spend too much time researching beyond what is on the worksheet, and they will go into more detail in the Explain portion of the activity.

Explain (20 min):

Preparation:

None.

Directions:

1. Show the students the slide with one hexagon and description (to be filled out) to the left. Tell students that each group will choose one of their images to Explain more deeply to the class.

2. Remind students how to replace the image in the hexagon with their image from WWT.
    a. Right-click on the hexagon with the number that corresponds to their mission objective.
    b. From the toolbar, select the dropdown from "Replace image" and choose "Upload from computer."
    c. Go to the location where the image was saved and select the image.
    d. The image should automatically update to be that student's image in the hexagonal shape.

3. Assign each group a slide (see the group numbers listed in the notes).

4. Give each group 20 minutes to investigate further the image they selected and fill out the slide material.

Elaborate/Evaluate* (5 minutes per group):

Preparation:

1. Prepare to have students present WWT Scavenger Hunt Student Slides to the whole class.

Directions:

1. Tell students that each group will have 4 minutes to present their slide to the class. Tell the students they should assign each portion of the slide to one student in their group (everyone should present).

2. Present the "Presentation Guidelines" slide and Give the students 10 minutes to work on what they would like to say and rehearse.

3. Before having students present, show the "Audience Guideline" slide.
    a. Each student is required to ask a question after the presentation of another group.
    b. The next presentation cannot proceed unless several unique questions (use your judgment on the exact number) have been asked about the previous presentation.

*The Elaborate portion of the activity is the presentation, and the Evaluate is the student's question and responses.

Extend (100 min):

Preparation:

1. Students will use the information collected during the scavenger hunt and the presentations to create a WWT tour to showcase the goals of the JWST mission. This "Extend" is advanced since making anything other than a very basic tour in WWT can be complicated. We recommend teachers explore making a tour in WWT before instructing students. Start by reviewing the "Getting Started" page linked below. You may want to offer this as an out-of-class extra credit assignment or an extra-curricular assignment to interested groups of students.
2. If you choose to have students narrate their video, make sure you understand how to use a device that can record mp3's.
3. Print JWST Tour Outline handout, one per group.
4. Print the Making Tour Guide (recommended) or provide digital access to students.

Directions:

1. Show students this website made by a recent CWU grad Sumiyyah Jalalyar (and the current teacher) on how to use the World Wide Telescope to make tours. In particular, you should direct students to the "Getting Started" page and ask them to watch the video (or present it in front of the class).

2. Hand out the Guide from Miss Jalalyar's page. You may want to guide students through the setup of a simple tour or allow them to read through the guide themselves.

3. Before having students make their JWST tour, ask students to make a 2 slide tour in class.

4. Provide students with the JWST Telescope Tour Outline handout.

5. Tell the students, "You will make a 5-8 slide tour that introduces the James Webb Space Telescope and either one or all 4 primary science goals. The full tour should be no longer than 5 minutes."

Guidance for adapting to remote learning:

This lesson is designed to be easily adapted to remote learning. The slides and worksheets can be provided and accessed by the students remotely Google Docs versions of each worksheet are provided on the first page of the lesson..

For the Explore, Elaborate, Explain portions, download and copy the google docs version of the worksheets. Give each group access to their worksheet so that they can work together remotely. After explaining WWT put groups in breakout rooms and get them started on the scavenger hunt!