Get Focused

Goals

- Apply knowledge of lenses.
- Use the engineering design process to develop a product.
- Estimate size and calculate magnification power.
- Write to explain telescope use to end users.

Video Overview

Video host Michael DiSpezio visits the observatory at the Herrett Center in Twin Falls, Idaho. He speaks with the observatory director, Chris Anderson, and explores several kinds of telescopes, including the observatory's computer-controlled, 24-inch reflecting telescope.

Background

Telescopes work by collecting and focusing light. They do this by using lenses, mirrors, or a combination of the two. A simple two-lens refracting telescope requires a pair of lenses with compatible focal lengths. A random pair of magnifying glass lenses will not produce a usable image. One typical lens combination is a large, plano-convex objective and a small plano-convex eyepiece. A second combination uses a double-convex objective lens and a plano-concave eyepiece lens. To work well, the lenses must be aligned center to center and with their faces parallel. This requires firm mountings for the lenses and tightly nesting tubes.

Standards Addressed By This Module

Content Area	Standards
Science	*National Science Education Standards* Physical Science, CONTENT STANDARD D: As a result of their activities in grades 5–8, all students should develop an understanding of • Transfer of energy "Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object— emitted by or scattered from it—must enter the eye."
Technology and Engineering	*ITEA Standards for Technological Literacy* 2. Students will develop an understanding of the core concepts of technology. 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. 9. Students will develop an understanding of engineering design. 11. Students will develop the abilities to apply the design process.
Mathematics	*Common Core State Standards for Mathematics* 4.MD.6 Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.
21st Century Skills	Creativity and innovation, critical thinking and problem solving, communication, collaboration, information literacy, media literacy, information and communications technology literacy, flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, and leadership and responsibility

Materials

Required

- masking tape
- nesting cardboard tubes
- poster board
- protractor
- ruler, meter stick, and tape measure
- scissors
- several pairs of lenses (see Teaching Tips)

Suggested

- aluminum foil
- black paper
- cardboard
- digital camera
- foam board
- glue
- modeling clay
- newspaper
- paper cups
- plastic wrap
- rubber bands
- shoeboxes
- string
- tape
- word processing and design software

Teaching Tips

Go over some very simple ray tracing diagrams on the board. Emphasize the basic designs of the Galilean and Keplerian telescopes. Leave these and the ray tracing diagrams up on the board for reference. Let students know the benefits of a fixed focus telescope and a telescope that allows for adjustment in focusing. Remind students how to figure out the focal length of a lens as mentioned in the student handout. **CAUTION:** Make sure students follow sun safety guidelines and never look directly into the sun or an eclipse, with or without a telescope.

Troubleshooting

Remind students of the importance of alignment when it comes to setting up the lenses. The lenses should be parallel with their centers lined up.

Have students measure the focal lengths of all the lenses before they begin designing or building their telescopes.

Be sure to divide the classroom up into small groups. Make sure that each group has plenty of options for lenses and materials.

Lens focal lengths need to be matched for telescopes to work well. The following pairs of convex lenses will work:

- 444-mm objective paired with 50- or 150-mm eyepiece
- 200–300-mm objective paired with 25–75-mm eyepiece

THE PROBLEM

You may wish to present a brief history of early telescopes, emphasizing the great accomplishments early astronomers made with technology similar to what the students are building. Bringing in a telescope and explaining how it works would be helpful as well.

THE CONSTRAINTS

Harder—Set up parameters of durability. Instruct the students to build the best telescope they can and then build an outer structure that will increase the instruments lifetime but not interfere with its usefulness.

Harder—Have students build a stable base that can be used to aim the telescope.

Easier—Provide the students with preassembled kits—restricting them to a certain design option.

RESEARCH and BACKGROUND

Preparation Make copies of the worksheets for students. Begin gathering materials.

Web Search Keywords concave and convex lenses, Galilean telescope, Keplerian telescope, refraction, focal length, ray tracing.

Discussion Questions

- **What obstacles might an astronomer in Galileo's time face?**
- **If you could have any materials you wanted to build a telescope, what would you pick? Why?**

Completing the Student Page

Students should realize how concave and convex lenses vary in their ability to refract light. Using different lenses can seriously improve or diminish the effectiveness of their design.

PLAN and BUILD

Preparation Prepare sets of materials. Plan a time and place for students to test prototypes before their final build. Review the details of the challenge with students.

Discussion Questions

- **What is the most difficult requirement for this challenge? Why?**
- **Why is the alignment and placement of the lenses key to this challenge?**

Completing the Student Page

The student page is designed to document the materials and challenge details that you select. Be sure that students understand the challenge before they begin designing and testing.

TEST and IMPROVE

Preparation To collect data on their telescope, have students set up a test object at a fixed distance from setup. Use of a digital camera would facilitate accurate comparison of output. Also, getting feedback on how well and accurately the telescope magnifies the object would be very helpful.

Discussion Questions

- **What differences would you expect between testing your telescope indoors and outdoors? Viewing an object in the distance or in the sky? Why?**
- **What consistently works well with each of the designs you tested? Why?**
- **How would using more expensive materials affect the final product?**
- **What other variables might affect your telescope?**

Completing the Student Page

Make sure the telescope placement, distance, and lighting is equivalent when students test each prototype.

Ask students to explain why it is useful to record the quality of images for each viewing.

If time allows, as class project, build a model with the design features that worked best from each of the final models. You might also try, as a whole class project, building a Galilean or Keplerian telescope.

REDESIGN

Preparation Prepare replacement materials. Circulate and check in with all teams and deal any major, common design problems as a class.

Discussion Questions

- **Can you use a drawing or scale diagram to help solve your design problem?**
- **What can you do to improve the fit, alignment, or position of the lenses?**

Completing the Student Page

Making any optical tool takes careful work. As much as possible, remove time pressure from students for this project. Encourage slower, more careful work.

Assessment

Formative Assessment

Use the student worksheet pages and suggested responses (below) to guide student progress during the module.

Student Page Answers

RESEARCH and BACKGROUND

1. Refracting telescopes and reflecting telescopes are two types of telescopes.
2. Concave and convex are two types of mirrors and lenses. Concave lenses curve inward like a saucer. Convex lenses curve outward like the side of a balloon.
3. Galilean and Keplerian are two basic types of optical telescopes.
4. The focal length of a lens describes well it converges or spreads out light waves.
5. The best place to build an observatory is at a high altitude, away from well lit communities.

PLAN and BUILD

6. Answers will vary. One solution is wedging a lens in a circular hole in a cardboard disk.
7. The tubes allow you to focus and fitting tightly keeps out unwanted light.
8. Put a meter stick or ruler against a wall and slide the lens along it until you have the smallest dot of focused light on the wall. When you measure the distance from the middle of the lens to the wall, or floor, that is your focal length.
9. You need to know the date, your location, a compass direction to point, and how high above the horizon to look.
10. Answers will vary. Students will likely experiment with tripods and boxes.

TEST and IMPROVE

11. Students should be able to compare the clarity of image provided by the telescope with that of their normal vision.
12. Students should be able to estimate how much larger the image from the telescope is in comparison to normal vision.
13. Answers will vary. Students should be able communicate design and building process improvements.

REDESIGN

14. Answers will vary.

15. Answers will vary. You may wish to review students' redesign plans before they begin.

COMMUNICATE

16. Answers will vary. Suggest that students think outside the box and imagine what is possible.
17. Answers will vary based on students’ models. Students should be able to use their records of problem solving and final model to recommend ideas to try and ones to avoid.
18. Data tables will vary. Students should notice that the estimate of magnification power (column 4) should be similar to the magnification power calculated in the next question.
19. Answers will vary. Students should notice that this calculation of magnification power is very similar to the one given in column 3 of the previous question.
20. It is how many times as great the image is compared to the object seen without the magnifier.
21. Answers may vary. Students may lack the skill to make visual estimates of size. Check to be sure that students aren't adjusting data for a better match.
22. Answers may vary. Students should develop a problem solving attitude and always double check their assumptions.