4

Oh My Stars!

For thousands of years, the night sky has been a source of wonder and intrigue, and the desire to understand it has led to major advancements in science, technology, engineering, and mathematics. This project will spark and extend children's curiosity about space. The chapter suggests technologies to support exploration of the night sky; science investigations to understand patterns and relationships among the sun, moon, stars, and planets; mathematics tasks focused on the base-ten number system and operations; and an engineering design challenge to build their own telescope or planetarium.

ISTE Standards for Students

The uses of technology in this chapter are most aligned with the following ISTE Standards for Students. Science activities recommend that children use technology to create and share their own weather forecast. Technology learning is also supported when students maintain journals online, engage in synchronous or asynchronous discussion with peers using various tools, or choose digital artifacts to extend and communicate their knowledge.

Empowered Learner

1c. Students use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.

Knowledge Constructor

3a. Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.

3d. Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions.

Computational Thinker

5b. Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making.

Innovative Designer

4d. Students exhibit a tolerance for ambiguity, perseverance and the capacity to work with open-ended problems

Materials, Time, and Supervision

Table 4.1 lists the materials required to engage with this activity, as well as those for projects that children can elect to do, depending on time constraints, interest, and availability of materials. As always, adults should be mindful of safety considerations as students engage with sharp objects or materials that might break, such as lenses. Students who live in locations with obstructed skies or major light pollution may benefit from a night visit to a location where they can more easily view the night sky, but digital alternatives are also provided if this is not accessible.

TABLE 4.1 Project Materials

REQUIRED	OPTIONAL
• Connected device (laptop, desktop, tablet, or smartphone) • Writing utensil (pen, pencil) • Paper • Crayons, colored pencils, or markers	• Styrofoam ball • Long tube (empty paper towel or gift wrap cardboard tube) • Duct tape • Two convex or magnifying glass lenses (preferably different sizes) • Black or dark umbrella • Object to poke holes through fabric (needle, sharp pencil, etc.) • Smartphone or tablet • Telescope

The project is designed for a few hours each day over one or two weeks, plus some night observations when possible. Ideally, the project would span over the course of at least two weeks so that children can collect observational data over a longer span of time. Children can complete most of the activities with some adult support to get started and then work independently. Night sky viewings and the engineering project may require additional adult supervision to ensure safety, especially for young children.

Resources to Explore and Inspire

Technology and space seem synonymous in many ways. From innovative ideas for space travel to increasingly precise ways of viewing planets and stars, technology continues to expand the human understanding of space. We can also use technology to expand children's understanding of space and to pique their interest in learning more. Children can visit the NASA website or YouTube channel or watch NASA TV to find an amazing amount of information about outer space, such as videos of spacewalks, educational talks from astronauts aboard the International Space Station, and information about aspects of daily life in space such as eating, sleeping, or toilets.

The science activities in this chapter reference additional technologies that can help children observe the night sky. Online applications or mobile apps for smartphones or tablets allow children to identify stars and planets, and many of these apps include augmented reality to identify constellations and other objects in the sky.

Examples of such apps include Star Gazer+, Star Walk, and Sky Guide. These sorts of technologies can augment children's observations of the night sky or allow them to see what might not otherwise be visible from some locations. Table 4.2 summarizes some of the technology resources that educators and families may find useful throughout this chapter.

TABLE 4.2 Resources to Explore: Oh My Stars!

RESOURCE	DESCRIPTION	GRADE LEVEL	CODE
NASA for Educators	Collection of space-focused online resources, games, and activities.	K–5	qrgo.page.link/6pnuQ
Jet Propulsion Lab (JPL)	Space-focused STEM education resources, such as classroom and family activities, demonstrations, games, and labs.	K–5	qrgo.page.link/PELZg
Stellarium	View live, on-screen representations of the night sky from any location.	K–5	qrgo.page.link/oA5aq
NASA STEAM Innovation Lab	Connects educators, families, and children with digital learning using cutting-edge technologies.	3–5	qrgo.page.link/RTMyx

Science: Sun, Moon, and Stars

Science activities in this project emphasize observation, predictable patterns, and the relationship of the sun's brightness and distance from Earth. Certainly it's possible to discover many more scientific concepts through space-themed activities, and children may make additional scientific observations during this project. To help them keep track of their discoveries and progress, have students keep a night sky observation journal throughout the project; what they include in the journal will depend on the grade level.

NGSS Disciplinary Core Ideas for Science

Encourage K–2 children to observe predictable patterns involving the sun, moon, and stars. In later elementary grades, children should make observations about the brightness of stars to help support an argument about the sun, other stars, and relative distance from Earth.

K-2 ACTIVITIES	3-5 ACTIVITIES
1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.	**5-ESS1-1.** Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.

Getting Started

Throughout the science exploration for this project, be sure to emphasize prediction, observation, patterns children notice, and discussions about those patterns. This project can be paired with more traditional bookwork about moon phases, planets, and stars. The observations and inquiry in this project may well help children make better sense of the space science in their school curriculum—after all, capturing observations of the stars and moon can be quite difficult during normal school hours. The science learning in this activity can also be extended into the real world of citizen science, a way to crowdsource scientific discovery by inviting public participation in solving real-world problems.

Grade-Level Guidelines

Children of all ages can observe patterns in moon phases, sunrise and sunset, and relative location of planets and stars in the night sky. A telescope can be a useful tool for assisting with children's observations. Using an online virtual planetarium or stargazing app can help identify specific stars, planets, and constellations that might be otherwise difficult for children to distinguish in the night sky. Of course, things like sunset, sunrise, and moon phases are more easily observable if one has a clear view of the sky and agreeable weather.

Grades K–2

Beginning at young ages, children can observe and track the moon each night. If the moon is not visible (because of factors such as weather, location, visual disability, or bedtime), digital stargazing or planetarium tools, weather forecasting apps, and online sites can provide the needed information in a variety of formats. After one week of observing the moon, children should be able to observe differences, and two full weeks of observations offer even more noticeable changes. Because the focus in grades K–2 is on describing predictable patterns, be sure to ask questions that highlight patterns:

- What do you notice?
- What do you predict will happen next time?
- How does your prediction compare to what you observed?
- Is there a pattern in your observations? How do you know?

Encourage children to justify their predictions with observational evidence and discuss patterns they notice.

Young children may wonder if the moon actually changes shape each night. What a fun discussion can be had on this topic! To further explore why the appearance of the moon changes each night, try having children act out the phases of the moon in an activity from the Jet Propulsion Lab (QR code in Table 4.4) using only a pencil, a white Styrofoam ball, a light, and a dark room. Activities such as these also provide an opportunity to introduce formal science vocabulary such as *waxing, waning, crescent, gibbous, new moon,* and *full moon*.

Alternatively, observations could focus on sunrise and sunset. It's unlikely for most times and locations that elementary children will be awake to observe both the sunrise and sunset, so instead, have children observe and collect data about the sunrise or the sunset, or look up data from online sources or weather forecasts on television.

Grades 3–5

Children in older grades can make observations about the relative brightness of stars as compared to the sun. Observing the night sky might begin with noticing when the first "star" appears in the sky. However, virtual planetariums and star-gazing apps will reveal that the first visible "star" isn't usually a star at all, but rather a planet. As the sky darkens, students may take note of stars that shine brightest and those that are barely visible. Ask children to consider why they think some stars appear brighter than others. Some likely responses will include the size of stars (e.g., bigger stars look brighter), the distance of stars from Earth (e.g., closer stars look brighter), or just that some stars are brighter than others (just as some lights are brighter than others). The eventual goal is for children to make an argument, using evidence, that observable brightness of stars depends on the relative distance from Earth. Rather than telling children this, let them discover and make this argument themselves based on authentic data they gather with the assistance of technology. Frequently ask questions to help children make these realizations:

- What do you notice?
- What do you wonder?
- Is there a pattern?
- What does the data show?

The vastness of the night sky, as well as measurement/location precision accessible to most elementary children, can make documenting these observations quite challenging. With adult permission and supervision, children might use tools embedded within sites or apps. Adult guidance is especially important for sites that are not designed for children. Help children safely explore sites that may have unpredictable advertisements embedded, and guide children to find relevant information within advanced sites that may overwhelm young children. For instance, Stellarium has an Observe feature that allows logged in users to maintain an astronomical log book. Depending on the specific digital tool, children may be able to click on specific stars to access the name of the star, its magnitude, distance from Earth, and much additional data. For this activity, it is important that children can identify or look up the names of particular stars, either from constellations (e.g., Big Dipper or Orion's Belt) or through a digital tool.

Prompt children to record the names of the four brightest stars they see and the names of four less bright stars they see. Then ask them to record the distance from Earth for each star they identify. A table, such as the example shown in Table 4.3, can be helpful for recording observations and noticing patterns. Depending on the data points selected, most children should notice that brighter stars are closer to Earth while dimmer stars are farther away. However, beware that these rough observations can be imprecise and some stars that children perceive as bright might actually be more distant than ones that appear less bright. For example, Deneb might look bright in the sky even though it is estimated at 1411.95 light years from Earth! In this particular case, Deneb is a supergiant that is especially luminous. Consider asking the child to collect more data points (list additional stars) to more clearly reveal the relationship between relative distance and apparent brightness.

TABLE 4.3 Sample Star Observation Table

STARS THAT LOOK BRIGHT		STARS THAT DO NOT LOOK BRIGHT	
Name of Star	**Distance**	**Name of Star**	**Distance**
Vega	25.04 light years	Kochab	130.93 light years
Capella	42.80 light years	Sadr	1832.37 light years
Arcturus	36.72 light years	Polaris	432.57 light years
Merak	96.5 light years	Tania Australis	331.27 light years

Source: Stellarium-web.org

After comparing the perceived brightness and relative distance of stars in the night sky, ask children to describe the brightness of the sun (emphasize that they should never look directly at it!) and make predictions about the sun's distance from Earth. Most children will accurately predict that the sun appears brighter, is closer to Earth than the other stars, and is bigger in the sky. However, kids may be surprised to learn just how much closer the sun is—8.3 light *minutes*, or 0.0000158 light years from Earth. Further discussion and exploration might focus on the observable size of the sun from Earth and the fact that our sun lights up the entire sky for several hours each day, whereas even the closest other stars are just a dot in the night sky. If the notion of light years is not familiar to children, they can learn more about it online, at sites such as NASA's Space Place. Table 4.4 summarizes a variety of technology resources that can support the science concepts in this chapter.

TABLE 4.4 Science Resources for Sun, Moon, and Stars Activities

RESOURCE	DESCRIPTION	GRADE LEVEL	CODE
PBS Kids	Space-focused citizen science activities.	K–5	qrgo.page.link/a2rpH
Moon Phases	Online tool with up-to-date information about moon phases.	K–5	qrgo.page.link/VzduA
Jet Propulsion Laboratory	Hands-on moon phases activity.	1–5	qrgo.page.link/mG8Kd
Sky and Telescope	Description of Deneb, a bright but distant star.	3–5	qrgo.page.link/AuaCf
NASA Space Place	Description of what a light year is.	3–5	qrgo.page.link/a48c2

Math: Place Value and Comparison

Understanding space involves understanding a lot of mathematics. Yet, much of that mathematics is far too advanced to be appropriate for elementary children. For instance, the distance between the sun and Earth is 0.0000158, or 1.58×10^{-5} light years. Using this context as an opportunity to talk about scientific notation seems logical and might be accessible to some elementary students. But scientific notation involves understanding decimals, exponents, and negative exponents, and it does not appear in the CCSSM until Grade 8. Instead of focusing on mathematics that is more advanced than many elementary children are ready for, observed data and mathematics history allow us to make more developmentally appropriate mathematics connections.

Getting Started

Adults and children, alike, might be surprised to learn that thousands of years ago, the ancient Babylonian civilization in Mesopotamia had a number system sophisticated enough to compute lunar eclipse occurrences and planetary speeds. Figure 4.1 shows a tablet inscribed with eclipse calculations, dating back more than 2,200 years.

Figure 4.1 This Cuneiform tablet shows eclipse calculations from ancient Babylonians.

CCSSM Math Content Standards

The mathematics in this project emphasizes place value concepts, including the importance of zero and how place value can be used to compare numbers. Math activities in this project support math standards in K–5, as shown here.

K–2 ACTIVITIES	3–5 ACTIVITIES
CCSS.MATH.CONTENT.1.NBT.B.2. Understand that the two digits of a two-digit number represent amounts of tens and ones. **CCSS.MATH.CONTENT.1.NBT.B.3.** Compare two two-digit numbers based on meanings of the tens and ones digits, recording the results of comparisons with the symbols >, =, and <. **CCSS.MATH.CONTENT.2.NBT.A.1.** Understand that the three digits of a three-digit number represent amounts of hundreds, tens, and ones; e.g., 706 equals 7 hundreds, 0 tens, and 6 ones. **CCSS.MATH.CONTENT.2.NBT.A.3.** Read and write numbers to 1,000 using base-ten numerals, number names, and expanded form. **CCSS.MATH.CONTENT.2.NBT.A.4.** Compare two three-digit numbers based on meanings of the hundreds, tens, and ones digits, using >, =, and < symbols to record the results of comparisons.	**CCSS.MATH.CONTENT.4.NBT.A.2.** Read and write multi-digit whole numbers using base-ten numerals, number names, and expanded form. Compare two multi-digit numbers based on meanings of the digits in each place, using >, =, and < symbols to record the results of comparisons. **CCSS.MATH.CONTENT.5.NBT.A.3.A.** Read and write decimals to thousandths using base-ten numerals, number names, and expanded form, e.g., $347.392 = 3 \times 100 + 4 \times 10 + 7 \times 1 + 3 \times (1/10) + 9 \times (1/100) + 2 \times (1/1000)$. **CCSS.MATH.CONTENT.5.NBT.A.3.B.** Compare two decimals to thousandths based on meanings of the digits in each place, using >, =, and < symbols to record the results of comparisons.

What might be even more surprising is that Babylonians managed to do this in a base-sixty number system (as opposed to our base-ten system) and with only two number symbols (as opposed to the ten digits that comprise modern numbers). More surprising still is that the Babylonians had no symbol for zero! Imagine making precise calculations about celestial bodies millions of miles away from Earth without a symbol for zero! Halfway across the world, in what is now Central America, the ancient Mayan civilization devised their own highly precise number system. The ancient Mayans devised a base-twenty number system using only three symbols: a line or stick to represent five, a dot or pebble to represent one, and a shell to represent zero. This was the first known widespread use of a symbol for zero.

You might ask, what does this have to do with teaching elementary kids about math? First of all, communicating basic math history to children conveys that the math they learn was created—it's not some mystical force from another realm. This can help address student perceptions "that mathematics is closed, dead, emotionless, all discovered" (Bidwell, 1993, p. 461). Historical context can, instead, humanize mathematics as a subject that is dynamic, open, and interesting. Secondly, highlighting the mathematical contributions from diverse civilizations around the world communicates that mathematics comes from and belongs to children of all backgrounds. Finally, this specific story about zero in ancient number systems sets the stage for place value learning relating to calculations in astronomy.

Grade-Level Guidelines

One might wonder how Babylonians could make sense of numbers without a zero. Evidence suggests that, since numbers were often used for trade and commerce, interpreting numerals without zeros depended on context (Jones, 1957). Without a symbol for zero in our number system, 12 could mean 12, 102, 120, 1002, 1,000,000,020,000. If you were at the market buying a dozen eggs, you'd recognize 12 to mean twelve. Or, if you're referring to the age of a great-grandparent, 102 is the interpretation that makes the most sense. On the other hand, the distance in kilometers between Venus and Mars (about 120,000,000 km) is not contextually obvious.

But what does zero and comparing numbers by place value have to do with the space theme of this project? For one, both the Babylonians and Mayans applied their advanced number systems to make sophisticated astronomical calculations and predictions that resulted in highly accurate calendars. Zero is an important mathematical advancement, but especially so for the enormous and miniscule quantities in astronomy. Secondly, this example demonstrates how to use context and questions to connect math and science content that may not be as obviously related.

Grades K–2

You can help children in younger grades learn about the importance of zero and apply place value in contexts involving space.

Invite children to think about context and quantity in ways that highlight why place value is important in our number system (Figure 4.2). They help make meaning for common types of tasks children might encounter, and they also invite quantitative reasoning and justification. The first three prompts have obvious correct answers (unless Booker Elementary School has an enormous lunch room). The last three prompts are less obvious. There could be 96, 906, 9,006, or more fish in a pond; many different answers could make sense. And while the last two questions technically have correct answers (1,300 and 239,000, respectively), we wouldn't reasonably expect children to determine the quantities based on context alone. The last three questions show why zero is so important in a place value system.

The following numbers are missing some zeros. Read each story problem. Fill in the blanks with how many zeros you think are missing from the number. Explain why your answer makes sense.

Ms. Lopez has 2_____ students in her first grade class.

Booker Elementary School has 1_____8 seats in the lunchroom.

Abigail's dad is 4_____ years old.

There are 9_____6 fish in the pond.

Jupiter is so big that 13 _____ Earths could fit inside of it.

The moon is about 239_______ miles away from Earth.

Figure 4.2 Children solve missing zero problems to deepen understanding of zero and place value.

Children commonly compare numbers using greater than (>), less than (<), or equal (=) symbols, and place value understanding is essential for these comparisons. For example, if comparing two whole numbers with different numbers of digits, the number with more digits is greater. Beware though—this is often generalized to decimals where the rule no longer holds true. Place value understanding also helps kids understand that, when comparing two whole numbers, they should begin by comparing the digits in the greatest place values.

Grades 3–5

Students in later grades can use the data they collect from observing stars to learn and apply operations based on properties of place value. Rather than solving decontextualized "naked number" problems that look like 37 > 25, the same mathematics problem could be contextually posed as: *Write an inequality to show whether Vega or Arcturus is farther away from Earth.* or *Write and solve three questions and inequality problems from the data in the table* (see Table 4.5).

TABLE 4.5 Distances of Selected Stars from Earth

NAME OF STAR	APPROXIMATE DISTANCE FROM EARTH *(in Light Years)*
Vega	25
Arcturus	37
Capella	43
Merak	100
Kochab	131
Polaris	433
Sadr	1832

Approaching inequalities in this way may be more challenging, but it also provides more opportunity for learning. Students both solve and generate problems, using mathematical notation and comparisons, applying data from tables, and connecting with science content. You can tailor the activity to different grade levels by choosing the data or parameters for collecting data. Whereas the two-digit and three-digit whole numbers in Table 4.5 could be appropriate for first and second graders to compare, the observation data in Table 4.3 includes decimal quantities that are more appropriate for fifth graders to compare.

Engineering: Aerospace Engineering

Types of Engineering for Kids' Exploration

As part of this project, kids can learn about STEM careers related to space. In particular, this is a good chance to learn about the field of aerospace engineering. It's not unusual for kids to dream of being an astronaut when they grow up, but children can scan the QR code to read about the broader range of career possibilities within aerospace engineering and design small-scale projects focused on space.

Elementary children can't engage in the authentic work of aerospace engineers, but they can do fun, classic activities such as making paper airplanes and testing how far they will fly. With the proper materials (two convex lenses or magnifying glasses, a cardboard tube, tape or glue, scissors, and a pencil), kids can engineer their own telescope for observing the night sky. A quick online search of "make a telescope" will yield many variations on this project so that families can appropriately guide children with this challenge. Don't have or can't get two lenses? An alternative space-themed design challenge is to create your own indoor planetarium using a black or dark-colored umbrella, chalk or a pencil, an object sharp enough to pierce the umbrella fabric, a flashlight, and a dark room. To design their own indoor planetarium, children can follow these steps:

1. Use chalk or a pencil to mark the location of prominent stars or constellations on the underside of the opened umbrella.
2. With adult guidance, use a sharp object to poke holes at the locations of the stars. Try to make larger holes for brighter stars and smaller holes for dim stars.
3. Stand under the umbrella in a dark room with a light source above (flashlight or light from a phone or other device).
4. Enjoy your own personal planetarium!

NGSS Engineering Design Standards

The engineering design challenge in this chapter provides opportunities for children to develop understanding of the NGSS Engineering Design Standards identified here.

K–2 ACTIVITIES	3TEACH ENGINEERING5 ACTIVITIES
K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem	**3-5-ETS1-1.** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

Extensions and Connections

Entertainment. The list of movies, television programs, and video games about space is far beyond what can be listed here. From blockbuster science fiction franchises to films such as *October Sky* (PG) and Disney Pixar's *WALL-E* (G), many child-friendly space-themed movie options exist. The movie *Hidden Figures* (PG) tells the story about how three African-American women at NASA provided the STEM knowledge for successfully launching astronaut John Glenn into orbit. Television programs such as *Space Racers* or PBS Kids' *Ready Jet Go!* entertain and educate. Many popular video games are also set in space. One that is appropriate for young children and combines science learning with play is *Kerbal Space Program* available for PC, Xbox, and PlayStation platforms.

Children's Literature. To combine reading with this STEM project, children's books about space make good accompaniments. Nonfiction books such as the Who Was? or What Was? series that includes NASA and prominent astronauts and astronomers, child-friendly space encyclopedias and reference books, or books such as *Astrophysics for Young People in a Hurry* by Neil deGrasse Tyson can expand children's understanding related to space and key figures. Margot Lee Shetterly's *Hidden Figures* books for children, *A Moon of My Own* by Jennifer Rustgi, and *Mousetronaut* by astronaut Mark Kelly are other examples of children's books that complement this project.

Writing. Given the wealth of nonfiction children's books about space, children might write about what they learn in a book of their choice, supporting their writing with text-based evidence. Younger children could also make a picture book about their moon phase observations.

Fine Arts. To connect with music, children could listen to space-focused songs from the *Here Comes the Science* album by They Might Be Giants. Challenge children to make up their own song about space. To incorporate visual arts, children could design their own star constellation. Given a dark printout of the night sky and chalk or a white crayon, children could draw a constellation, name it, and make up their own backstory for it.

Computer Science. Block programming such as Scratch or code.org activities can be used to create projects focused on stars, planets, the moon, or space in general. If children have access to codeable robotics such as Sphero or Dash, they could program the bot to orbit around Earth like the moon, or around the sun like a planet. Children with access to an Ozobot could draw a model of planetary orbits and use the bot to rotate while following the marker paths as a planet might.