World Space Week
Teacher Activity Guide

For use in grades K-12 during annual

World Space Week, October 4-10

Note to Middle School English & Science Teachers

Please also see the World Space Week Heinlein Activities Guide, available for free at www.worldspaceweek.org

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Introduction

World Space Week: A Tool for Teachers

The United Nations has declared World Space Week as October 4-10 annually. World Space Week is now celebrated in some 50 nations. This week is thus the ideal time each year to use space to excite students about learning. Today's youth have so much to benefit from space. Space has changed their world and offers even greater excitement for their future. This guide helps science and math teachers use this natural attraction of youth to space.

What is World Space Week?

World Space Week is an international celebration of the contribution that space science and technology makes to the betterment of the human condition. During World Space Week, events and educational programs related to space are held globally. By synchronizing many events, a news story is created that attracts media coverage. This efficiently educates people throughout the world about space and demonstrates widespread public interest in space. For a list of locations and planned events, please see www.worldspaceweek.org.

When is World Space Week?

The dates of World Space Week, October 4-10 annually, commemorate key milestones in space: October 4, 1957 was the launch date of Sputnik I, the first human-made Earth satellite. The first international space treaty, the Outer Space Treaty, went into effect on October 10, 1967.

How to Use this Activity Book

To help you use World Space Week in the classroom, enclosed are a variety of stimulating K-12 science and math activities. These activities were designed by teachers to use space to motivate children while teaching essential science and math knowledge and skills. The activities require little or no teacher preparation time and most can be easily tailored for use at all grade levels.

World Space Week Theme

Each year, there is a theme for World Space Week. You can find out this year's theme at www.worldspaceweek.org. You are encouraged to ask your students to explore, develop, and apply this theme throughout World Space Week.

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World Space Week Association, a non-profit organization, supports the United Nations in the global coordination of World Space Week. Founded in 1981, the Association helps the UN expand World Space Week and serve participants. The Association does not advocate any space programs or policies, but encourages worldwide participation in World Space Week. It is led by volunteer Directors and Officers from around the world and is supported by voluntary contributions. For more information, please see www.worldspaceweek.org.

Getting Started

Teacher's Quick Start Guide

To participate in World Space Week, here's what you should do:

Before World Space Week

- Select activities to use during World Space Week (starting on page 6) and collect any materials.
- If you received this guide as part of the Teacher Kit:
  - Post the large color posters in your classroom and or hallway.
  - Make copies of the Student Certificate.

Optional Preparation

- Tell other teachers about World Space Week and make them copies of this Guide.
- Design your own activities – Space can be used to teach virtually any academic subject!
- Plan an event during World Space Week to involve parents or the community (see "Going Beyond the Classroom" on this page).
- Add your classroom's or school's World Space Week plans to the global calendar at

During World Space Week – October 4-10

- Use space as a theme throughout the week to excite your students about learning.
- Conduct other selected activities
- Document what you do – Take photographs!

After World Space Week

- Teachers are encouraged to provide feedback on these materials using the on-line form at www.worldspaceweek.org/feedback.html or the paper form on the next page.

Going Beyond the Classroom

If you want to involve parents or your community, consider holding an event during World Space Week. Many teachers have even received media coverage! Here are some ideas:

> *Competition and/or exhibition of student space projects • Student award event for projects • Concert with space-related music • Oral reading of space stories • Films about space • Guest speakers on space • Model rocket launch • Planetarium or science museum field trip • Space art exhibit • Telescope "Star Party"*

For more event ideas, please see www.worldspaceweek.org

Additional Resources

Leading Space Organizations

Astronomical Society of the Pacific
    http://www.astrosociety.org/

Canadian Space Agency
    http://www.space.gc.ca/

Centre National d'Études Spatiales
    http://www.cnes.fr/

Challenger Center
    http://www.challenger.org/

China National Space Administration
    http://www.cnsa.gov.cn/

DLR
    http://www.dlr.de/DLR-Homepage

European Space Agency
    http://www.esa.int/

GLOBE Program
    http://www.globe.gov

International Astronautical Federation
    http://www.iafastro.com/

Japan Aerospace Exploration Agency
    http://www.jaxa.jp/

Mars Society
    http://www.marssociety.org/

NASA
    http://www.nasa.gov/

National Science Teachers Association
    http://www.nsta.org/

National Space Society
    http://www.nss.org/

Planetary Society
    http://www.planetary.org/

Russian Federal Space Agency
    http://www.federalspace.ru/

Space Camp
    http://www.spacecamp.com/

Space Link
    http://spacelink.nasa.gov/.index.html

Space Foundation
    http://www.ussf.org/

Space Frontier Foundation
    http://www.space-frontier.org/

Students for Exploration & Development of Space
    http://www.seds.org/

United Nations Office for Outer Space Affairs
    http://www.oosa.unvienna.org/index.html

Young Astronauts
    http://www.youngastronauts.org/yac/

Other Space Education Web Sites

See SIA Links Page
    http://www.worldspaceweek.org/links.html

Local Resources

For local assistance with World Space Week, you might also try to contact any of the following in your area:

- Science museums
- Planetariums
- Astronomy clubs
- Model rocket clubs
- Observatories
- Government space centers
- Aerospace companies
- Astronomy departments at universities

Student Activities

LANCE'S LAB

Note to Teachers: This activity is written for students at various grade levels. During World Space Week, students design a laboratory for the International Space Station.

Objective

Imagine that pop star Lance Bass is going to live on the International Space Station (ISS) for 3 months. There is only one problem: he needs a place to live! Your mission is to design a Space Station module where Lance can live, record music, do experiments for educational purposes, and communicate with people back on Earth. Some things you may want to consider:

1. How will Lance carry out the day-to-day tasks of living: eating, sleeping, washing, etc.?
2. How will he record music?
3. How will he communicate with his friends and family and take care of business on Earth?
4. How will he relax and have fun?
5. Why should Lance go into space? How could he use his time in space to contribute to the exploration and utilization of space?

Activity

Design Lance's Lab during World Space Week, October 4-10. Students may (and are encouraged to) work on teams of up to 5 people.

Grades K-5

Draw one picture of the inside of Lance's Lab and one picture of the outside of Lance's Lab. Pictures must be on 8.5 x 11 paper and may be drawn in pencil, ink, marker, crayon, or colored pencil only (nothing that needs to be glued on).

Grades 6-8

Write a report (2000 words maximum, double-spaced, 12-point, Times New Roman font) describing the features you would design into Lance's Lab and the justification for your designs. Include an abstract, introduction, conclusion and bibliography. The bibliography will not be counted against the word limit. You may include two pages of drawings. Lance's Lab must have the same dimensions as the Destiny Lab module currently attached to the ISS—8.5 meters (28 feet) long and 4.3 meters (14 feet) in diameter—and you must show this in your diagrams.

You are also required to present your design and justifications for the design to 10 or more people. The presentation should take approximately 15 minutes and include a question and answer period. You are encouraged to prepare slides, practice, and dress professionally for your presentation.

Grades 9-12

Write a report (5000 words maximum, double-spaced, 12-point, Times New Roman font) describing the features you would design into Lance's Lab and the justification for your designs. Include an abstract, introduction, conclusion and bibliography. The bibliography will not be counted against the word limit. You are encouraged to include drawings and diagrams. Lance's Lab must have the same dimensions as the Destiny Lab module currently attached to the ISS—8.5 meters (28 feet) long and 4.3 meters (14 feet) in diameter—and you must show this in your diagrams. You must also decide where to attach Lance's Lab to the ISS (Assembly Complete) and show this in a diagram.

Include a schedule of activities for Lance to perform daily and a list of objectives for him to accomplish by the end of his 3-month mission. You are encouraged to relate Lance's activities to those of the astronauts currently living on the ISS and discuss how Lance's presence and activities would contribute to daily ISS operations and to the exploration and utilization of space.

You should present your design and justifications for the design to 10 or more people. The presentation should take approximately 15 minutes and include a question and answer period. You are encouraged to prepare slides, practice, and dress professionally for your presentation.

Research

In addition to visiting the Lance's Lab section of the World Space Week website (www.worldspaceweek.org), designers are encouraged to use the following resources (and more) to learn more about the International Space Station:

http://spaceflight.nasa.gov/station/
http://www.nasa.gov/
http://www.cnn.com/SPECIALS/multimedia/vrml/iss/
http://www.hq.nasa.gov/office/pao/History/SP-483/contents.htm

Designers are also encouraged to visit their public library to find books and newspaper articles about ISS.

SPACE WEB PAGE DESIGN

Objectives

The objectives of the Space Web Page Design Competition are to:

- Promote mastery of the Internet by students and build their confidence in web technology
- Encourage students to explore space-related resources on the web and be inspired by space

Overview

This is a fun, exciting activity that can be done by any grade level with access to computers and the Internet.

During World Space Week, students create web pages about space that relate to an academic area selected by the teacher. This uses space to excite students about learning.

Students can work individually, in teams, or as a class. Software such as Word or PowerPoint can be used to create basic web pages. Students are encouraged to incorporate modern web technology into their pages to learn how the Internet works.

Content Guidelines

Teachers should pick a specific class topic that is exciting and reinforces academic objectives. For example, a class topic could include:

- Grades K-5 – The planets, space art, space movies, the future in space, etc.
- Grades 6-8 – Celestial navigation, what satellites tell us about Earth, secrets revealed by the Hubble Telescope, space as the next frontier, international cooperation in space, etc.
- Grades 9-12 – New materials made in space, impacts of astronomy on religion, space in modern cinema, science fiction and science fact, the space race and the Cold War, etc.

The activity should start with a class discussion of the selected topic. Teachers should then describe the Web Page Design Activity, briefly discuss how to build a web page, and review the available resources (computers, software, books, etc.).

How to Build a Web Page

Teachers, if you have never built a web page, ask your students! Today's technology-savvy youth know much about computers and are fast learners.

The simplest way is to use a word processor that can save a document in web format. Students can use a program like Microsoft Word to design a page with a title, pictures, text, and links. To save as a web page using Word, click File, Save As, and select "Web Page" in the "Save as Type" field.

Students can also try simple web-authoring software, some of which can be downloaded for free (for more information, see www.knopfler.com/pc or www.cnet.com). Students should be encouraged to try these tools and learn how easy and fun designing a web page can be.

Space Resources on the Web

To explore space resources on the web, students should start with the links on page 5. Many of these sites then link to other exciting places to explore. Web sites with space-inspired music, art, and poetry, etc. include:

www.spacestory.com – By Astronaut Story Musgrave
www.novaspace.com – Novaspace Galleries

Sites with space images include:

http://oposite.stsci.edu/pubinfo – Hubble Telescope
images.jsc.nasa.gov – Human Space Flight

Students can incorporate photos, other multimedia elements, and interaction to communicate and tell a story. They could even have a quiz, puzzle, game, or slide show to make their page fun.

EGGNAUT…OR… HOUSTON WE MAY HAVE AN OMELET!

Grade Level: Primary and Middle School

The Problem: Your mission, should you choose to accept it, is to design and build a vehicle that will protect your Eggnaut from the perils of reentry. The objective is to have your Eggnaut survive the fall with out a crack.

Grades K-5	*Grades 6-8*	*Materials*
4	2	8.5" x 11" sheets of standard copy or typing paper
25	20	Drinking straws of any size with at least a 5"length
25	20	Popsicle or craft sticks/wood splints/tongue depressors
150 cm	100 cm	String of any size
150 cm	100 cm	Masking tape of any size
5	5	Rubber bands any size
1	1	RAW grade A egg
1	1	Pair of scissors

<u>*The Rules:*</u>

1) The reentry system must fit inside

   Primary - a space of 30 cm x 30 cm x 30 cm

   Middle - a space of 20 cm x 20 cm x 20 cm

2) Parachutes or helicopters are allowed.
3) A plumb line can be used to target the reentry vehicle onto the recovery zone.
4) All parts of the reentry system must be above the reentry orbital height of

   Primary - 2 to 3 meters

   Middle – 3 to 5 meters

5) The reentry system's mass must not exceed

   Primary - 400 grams

   Middle – 300 grams

6) It must land as close as possible to the center of the reentry zone.
7) You do not have to use all of the materials listed.

<u>*Questions to Consider:*</u>

1) How can I design my reentry system (capsule) to protect the eggnaut?
2) What can I design into my reentry system to make sure it lands in the center of the target area?
3) How am I going to slow it down?
4) Which of Newton's Laws of Motion are at work on the capsule and eggnaut?
5) Draw a plan of your system and explain how it is going to work and why?
6) Report your test results and

   Primary - why they happened and how you would fix them.

   Middle - why you think they occurred and what you could do to improve your design.

Grade Level: High School

<u>*The Problem:*</u> Your design team is to design and build a scale landing pad to be used in case of an emergency extraction from the new eggnaut orbital system. The landing pad must prevent a raw eggnaut from breaking after it has accelerated under the force of gravity for a distance of one meter or more.

<u>*Materials:*</u>

10, 8.5" x 11" sheets of notebook or copy paper

30 cm of masking tape

A RAW eggnaut (grade A large egg)

Plumb line for aiming (meter stick)

Modeling clay (50 to 60 g. lump as a practice egg; dents = cracks)

Triple beam balance

<u>*Specifications:*</u>

1) You may use only the materials listed; you do not have to use all of them.
2) Egg landing pads must stand by themselves. They cannot be taped to anything or held by anyone.
3) A cracked egg is a broken egg. If the egg bounces off the landing pad or the landing pad falls over allowing the egg to touch the floor, the egg is considered broken.
4) No parachutes or wings are allowed.
5) Use any technique that you may have learned in any science or mathematics class that will aid you in constructing the pad.
6) When you have completed the task, you will hand in a report that will have a drawing with a written description of your design with a prediction of how it will function. Repeat the results of the tests. Make suggestions on how to improve your design and explain exactly how these changes will function. You will also calculate the speed at which the egg is hitting the landing pad and the force of the impact of the egg on the landing pad. Show your work and include the formulas.

7) Your design will be scored on how successful you are in the egg drop and your report.

MAKE A CRITTER

The Challenge

Imagine that a new planet has been discovered – Betelgoose - your job is to design an animal to live there. Its a chance to let your imagination run wild …or maybe we should say "run wildlife."

Instructions

Read about what kind of world Betelgoose is and a few of the strange life forms already living there. Don't forget: the whole idea is to use your imaginations but still make good ecological sense with your decisions. The creature should have adaptations that prepare it especially well in body and behavior to thrive in one or more of Betelgoose's habitats.

For example, the gravitational pull on Betelgoose is stronger than that on Earth. Would your creature need special adaptations to handle that? If your creature lived in the tropics of Betelgoose, would it need a defense against swarms of O'Malley's Snips? As you read about Betelgoose you'll find examples of creatures that prey on your creature or be preyed on by it. How will your critter cope?

The Rules

1) Only one entry from each student or team.
2) You must describe the main habitat and climate in which your critter lives (for example, tropical forest floor). Use an 8-line paragraph minimum.
3) How does it move? Include both the form of locomotion and its organs for moving (for example, leaps on powerful hind legs). Use an 8-line paragraph minimum.
4) Is it a herbivore, carnivore, omnivore or other? What, specifically, is its main food and how does it get it? Use an 8-line paragraph minimum.
5) What other creatures does it prey on, if any? How does it defend itself against predators? Use an 8-line paragraph minimum.
6) How does it cope with Betelgoose's extreme seasonal changes? Use an 8-line paragraph minimum.
7) Is it solitary? Does it live in large groups? Describe its social behaviors. Use an 8-line paragraph minimum.
8) What else would you like us to know about your critter? Use an 8 line paragraph minimum.
9) You must include a drawing of your critter. Put in as much detail as possible but not a micro drawing.
10) No magical powers are allowed.
11) Everything on the planet Betelgoose must obey the know Laws of Nature.

Information about the imaginary planet Betelgoose

Planetary Location:

Sub sector: Span 175 located on the core ward edge of the spiral arm.

Regina Loran Star system. H-R White main sequence star with average surface temperature of 12,000 degrees C.

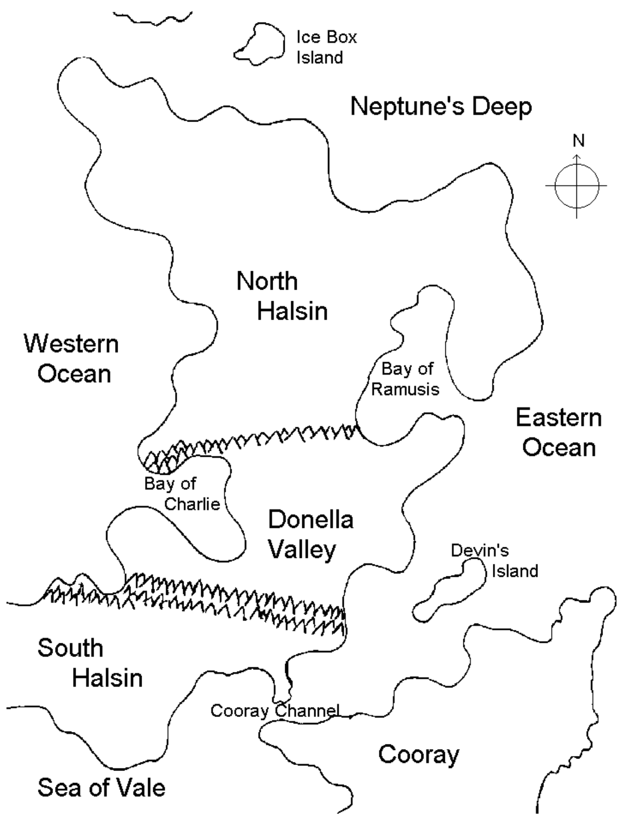
Diameter: 2,073,600 km.

Sun spins on its axis from left to right. 12 planets and 2 asteroid belts in system.

The Third, Fourth, and Fifth planets have conditions favorable to Earth based life forms .

Planetary Conditions:

Planetary diameter 11200 km. Gravity is 1.2 times Earth's gravity. Strong magnetic field. Nickel Iron Core. Some volcanic activity on the planet. Average distance from its sun is 298,000,000 km. Betelgoose circles its sun every 690 Earth days. Betelgoose length of day is 27 hours 25 minutes. Betelgoose tilts 25.25 degrees on its axis, causing seasonal changes. Betelgoose has both a northern and southern polar ice cap. The mountain range planet has 7 continents and is covered by 7 systems. Betelgoose also has its own version of Van Allen Radiation Belts and an atmospheric composition of 78% Nitrogen, 19% Oxygen, 1% Carbon Dioxide, 1% trace gases (similar to Earth), and 1% Argon. Atmospheric pressure is 1.05 times that of earth. Hydrographic percentage of coverage is 65% (surface covered by water). Overall average temperature is 3 degrees C cooler than the Earth's average temperature.



<u>*Regional Conditions*</u>

North Halsin – subarctic to temperate, dry

Donella Valley – temperate

South Halsin – temperate to subtropical

Cooray – tropical

<u>*Brief History*</u>

Betelgoose, discovered in 2232, is the fifth planet in Regina Loran system. Betelgoose has many species of plants and animals, including a number that have some intelligence. Planetary mineral survey indicates favorable condition for industrialization. The extreme tilt of the planet's axis makes for seasonal changes which are more extreme than on earth. These extreme changes have encouraged a wide variety of seasonal adaptations by Betelgoose's species. The biological survey of the plants and animals yielded a variety with adaptations to the local environment in their own specific ways. The classification of the life forms turned out to be remarkably similar to those of Earth. Among the more unusual species described so far are the following:

<u>*Excerpt from Biological Survey*</u>

Name: Halsin Sand Eels

Habitat: Sandy regions of North Elauos

These reptilian like animals resemble Earth snakes but have four small legs that they keep tucked close to their body most of the time. They are covered with heavy armored scales which stand up to the abrasives of the sands of Halsin rift Sand Depression. Each digit has a scoop like claw which helps the Sand Eel move through and on the sand. The Sand Eel deals with the increased gravity of Betelgoose with a more robust bone and muscle structure. Sand Eels eat insects, very small desert mammals and eggs. They are not very aggressive using camouflage and surprise to ambush their prey. They bury themselves deep in the sands to escape the frigid night of the rift.

Name: Lesser Betelgoose Hickory Palm

Habitat: Temperate Donella Valley

Although these trees look like Hickory Trees of Earth, they are not true hickory trees. Lesser Betelgoose Hickory Palm averages about 15 to 18 meters in height with a spread of 10 to 15 meters across. The tree has a shape like a hickory tree in growth habit but does not lose its leaves or go dormant like the hickory's of Earth. The bark resembles Hickory but it has a high number of strong fibers which resemble rope in their cross section making the tree very strong and are difficult to cut through. The trees inner trunk is very much like that of a palm tree and very high in food value. The plant also produces a nut which resembles the Hickory nut but is harder and larger. The tree structure makes it unusable for the most part as lumber.

Name: Great Betelgoose Hickory Palm

Habitat: Tropical rain forest of Cooray

Huge but very rare versions of the Lesser Betelgoose Hickory Palm, they can reach 50 meters, with a spread of 50 meters. All other characteristics are like those of the Lesser species.

Name: Neptune's Blankets

Habitat: Deep, regions of all oceans

Neptune' Blankets are something like a large flat jelly fish but weight nearly 35 Kilograms. They swim by rippling their bodies the same way as rays on Earth. They kill their prey by engulfing it and stinging it. Very little is known about these strange creatures, as live Neptune's Blankets have been sighted only briefly on several occasions.

Name: O'Malley's Snip

Habitat: Subtropical South Halsin and Cooray

The O'Malley's Snips are small insect like creatures no more than 1 cm in length with a wing span of 1.5 cm. They often appear from the brush in swarms of several hundred to thousands of individuals. They feed on the blood of mammals, birds and plants juices. They resemble a biting fly. Further study is needed to determine if they can transmit disease. They also migrate north during the long summer months.

Name: Golden Bell

Habitat: Forested and open areas of South Halsin, Donella Valley, Cooray

Golden Bell is the major ground cover on Betelgoose. There are large tracts of the little plant known as the Golden Bell. They are a brilliant golden yellow in color with the plants about the size of a softball, and a very tough skin and bell shaped base. They extract their nutrients and water from the soil and also use photosynthesis. Inside the bell shaped stems are soft fibrous tissues. Below ground the root system is entangled forming a mat.

Name: Snorks

Habitat: Exclusive to Donella Valley

Snorks are about the size and shape of a large prairie dog. They can walk upright, on their powerful hind legs, and have well developed grasping hands on their forelimbs. They are very rare and shy, so that they have not been well studied yet. Early observations show them to be as intelligent as a chimpanzee. With the climate of Betelgoose being cool, even in summer temperate zones, Snorks spend much of their time in large underground nests. These are heavily insulated with at least one emergency escape exit. Snorks have been observed using simple tools shaping them with their teeth. They have also been seen working together to drive off predators from the nest. Further study is called for to understand them.

"ZERO-G" GAME OR SPORT

This activity is to invent a game or sport that can only be played in Zero-G. This allows students to apply their love of sports while learning physics. Their game or sport must not work in a gravity field.

The Challenge

Your mission is to create a sport or game that people in space can play which will be interesting, exciting and fun. Your proposal for the new sport protocol must have the following:

b) A basic description of your activity and its rules and an explanation of how it meets the basics for a sport (exercise, interesting, fun).

c) A comparison of the playing of your sport on the Earth and in space. Describing the changes needed to play it anywhere (rule changes and equipment differences)

d) How the lack of any gravity affects the rules and equipment.

e) A mathematical analysis of the sport (middle/high school) along with or a qualitative analysis for the lower grades.

f) Investigations of sports protocols that would not be suited to space, with reasons and supporting information why they were rejected.

g) A fictitious news article describing the solar system's "Championship" match for your sport or game.

h) A drawing of the equipment and field with size or dimensions, etc.

STAR WATCH

This can be an exciting event for students and families. Pick a date during World Space Week in advance and notify parents. Be sure to cover enough basic information on astronomy so that information learned can be applied during the event. Have students bring binoculars or small telescopes and try to involve a local Astronomy Club. Have star charts available which show star positions relative to your latitude and local time.

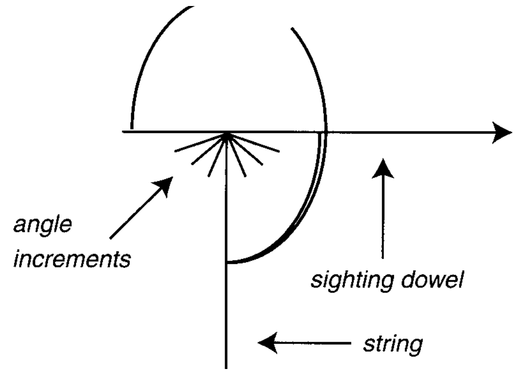
Select some distinct objects such as the Orion Nebula. Students can make an inclinometer (see below) and use it to locate these objects. Have contests for the first star seen, first planet seen, brightest star, constellations, or lunar features if visible.

Try to connect the following items to the activity: time, observations, coordinates, ecliptic, etc., or for daytime activities: sunspots, time calculations, and ratios of shadow effects.

If you have access to the Internet, you can view current images from the sun while staying in the classroom, e.g.:

http://umbra.gsfc.nasa.gov/images/latest.html

Safety Note: All students should be warned about looking directly at the sun without the aid of a solar viewing device that has been specifically made for solar observations.



OBSERVATION INCLINOMETER

Students build and use an inclinometer to find stars in the night sky. Students should sight along the dowel. The counter weight will hang such that the angle to the object can be determined on the protractor. A bearing reading can be taken such that the angle to the object and its bearing can be used to locate the object on the star map.

Materials needed:

- 1 watch
- 1 plastic protractor
- 1 star map
- 1 piece of twine or string (30 cm)
- 1 compass
- 1 counter weight (fishing weight)
- 1 flashlight with small red lens
- 1 dowel 40 cm in length

Students should glue the dowel along the straight edge of the protractor so that one end is flush with the end of the protractor and the rest of the dowel extends along the length of the straight edge. The string should be tied through the hole of the protractor's zero-point. Tie the counter weight to the other end of the string.

Note: Students should take timed interval measurements for determination of relative motion and change. Be sure to have students check their inclinometer and practice taking measurements of inclination to sighted objects.

SPACE ART

Students will be given the opportunity to develop a mural, picture, flip book, cartoon book, or sculpture that would relate to this year's World Space Week theme. Refer to art work that has an astronomical relationship. Suggested evaluation for art projects would be in originality, creativity, and knowledge.

TIMELINE

Using the Internet and/or other resources, students will explore information from the earliest records on astronomy and develop a timeline that is current through today. Use pictorial or artwork when appropriate to enhance the timeline.

BOARD GAME

Students will adapt or develop a board game which uses space exploration or space fact/knowledge as a framework. Students will establish rules for game. Games could be judged based on originality, creativity, knowledge, and structure. Students may participate in competition, both in development and playing the game. The game format could be developed for play on computer.

GREAT SCIENTISTS

Objective: To provide a framework in which students can develop an understanding, appreciation, and application of the history of science that has influenced space programs and our daily lives.

Task: Research key figures such as Galileo, Newton, Kepler, Einstein, Tsiolkovsky, Goddard, Von Braun, etc. relative to period in which they lived, what they discovered, how it is applied to space exploration.

Elementary

Dress in costume and demonstrate basic knowledge of their character. Could be done on the final day to culminate World Space Week activities. Students would present something about the person and their significance in space exploration. For example:

- Galileo: Could be done at a star party in honor of the telescope
- Newton: Could demonstrate the effect of gravity in the classic setting of the tree.
- Goddard: Could demonstrate rocketry by launching model rockets

Middle School

Students could write and perform a play where the characters above were brought to future. As an alternative, they could write for the school newspaper "interviews" with their characters, or broadcast a live "interview" across the school. They should emphasize the difference between now and then (how far we have come).

High School

Students would work in teams to develop an in-depth profile of the above characters and then present synthesis in the following possible formats.

- Conduct a debate on issues of science that the group as a whole would not have experienced. Teams will choose debater for their historical character. This would be most applicable in a large student body presentation.
- Develop and write a play which would bring the characters together in some type of setting with the purpose of exposing their thoughts and theories.
- Students could structure a special edition of the school newspaper framed around space and its benefits to society, and the roles of great scientists and engineers.

S U N D I A L

Materials needed:

- 1 piece of thick poster board
- 1 piece of plywood (1 meter square)
- 1 measured dowel (1/2 meter)

Students can make their own sundial by using a 1 meter square piece of plywood and thick poster board with a measured dowel. When the plywood has been cut to size, place the poster board on top of the plywood. Along one side of the board, measure 50 cm. and mark for the drilling of a hole the size of the dowel. The dowel should be placed in the appropriate size hole in the plywood. Using a compass, align the board edge with the dowel along the east/west line established with the compass.

Have students take hourly readings, beginning in the morning and mark the poster board along the shadow cast by the dowel. Be sure to mark the time of the measurement. Students should continue to take observations all during the school day or over a period of days. Be sure to keep the sundial in the exact same location while all observations are being made. Once initial readings have been taken and marked, continue daily observations.

Have students try to answer the following based on their observations:

1) Was the sundial effective for keeping daily time?

2) What limits the sundial in keeping time?

3) What can the sundial tell us about the motion of the Sun relative to the Earth?

4) What can the sundial tell us about the motion of the Earth relative to the Sun?

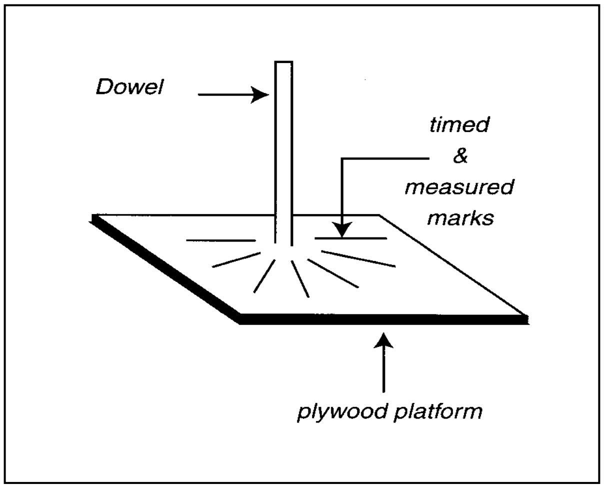
5) What can this tell us about ancient cultures' attempts to measure time?

Math Connection

Explain why the shadow cast by the dowel can be used to determine the height of a tree or some other tall object of an unknown height?

$$\frac{\text{Length of dowel}}{\text{length of dowel shadow}} = \frac{\text{height of object (x)}}{\text{length of object shadow}}$$

(Be sure to use a calibrated chronometer or clock to determine the measured marks for sundial.)



POPULAR MEDIA

An activity could unite both Science and English classes in a survey of science fiction literature from the 19th and 20th century that has inspired people about space. Example of such authors are Jules Verne, Isaac Asimov, Ben Bova, Robert Heinlein, Ray Bradbury, Arthur C. Clark, Jerry Pournelle, etc.

Students could review space-related film and/or television and determine their impact on public perceptions about space. Students can also determine if science is being used correctly. Examples are ET, 2001 A Space Oddesy, Independence Day, Apollo 13, Close Encounters, Star Wars, Star Trek, Contact, Lost in Space, Mission to Mars, Space Cowboys, etc.

Students could review news coverage of space and determine impacts on society. Does the coverage treat successes and failures equally? Does it balance coverage of government and non-government space activity? Does it fairly cover national vs. international space news? How does the amount and type of news coverage about space impact public opinion about space?

SUPER QUIZ

This can be a team- or group-based school-wide activity. The students will research and gather information as teams or groups based on the suggestions below or other appropriate categories related to space or this year's World Space Week theme. The group will then choose a format in which to display information and learning from (but not exclusive to) the list below. Review games format in order to ensure familiarity with games concept.

Students make or adapt a game

- Quiz Show game
- Strategy/Simulation Game
- Guessing Game (pantomime, charades)
- Expedition Game (what would you do if, or what would you need if)
- An online collaborative game of any of the above suggestions or a World Space Week Online Trivia Game.

Students help collect data and prepare questions for either a school-wide or class-oriented quiz. If conducted in an auditorium, the super quiz could be conducted as a "Jeopardy" or similar team-game format.

"Extra Credit"

- Students can "televise" the game using pictures and sounds to enhance the production. As an alternative students can produce a game that could be played on the Internet.

Categories of Information

Constants	Missions	Impacts
Universe	Comm Sats	Material s
Gravity	Apollo	Medicine
Time	Shuttle	Technology
Space	Space Station	Agriculture
Terrestrial	Hubble	Weather
Extraterrestrial	Mars Mission	Economy
	Planetary Probes	Communication
		Education

ASTRONOMY AND SOCCER

Soccer is one of the most loved sports in the world. A 100-yard soccer field could serve as a venue to compare distances in our Solar System. Hopefully, this exercise will add perspective to the vastness of our part of the Universe and to the learning of astronomy.

The first step in this exercise is to scale a soccer field (100 yards or meters) onto an 11" x 14" sheet of paper, e.g. let 2.50 cm equal to every 10 yards or meters Before plotting on your 11" x 14" soccer field, make two copies for future use. Next, locate the Sun on one goal line and Pluto on the other goal line. You can represent each planet as a small circle. The planet size does not have to be to scale, however feel free to use relative sizes to represent each planet, e.g. the circle for Jupiter will obviously be larger than the one for Mars. If you choose to represent the planets with relative size, plot the center of the planet at your calculated values. You may choose to color or highlight each planet with its individual characteristics, e.g. red for Mars, definitive rings for Saturn, and the belts and zones of Jupiter. Using the information and equation below, calculate the average distance of each planet from the Sun scaled to the soccer field on your 11" x 14" paper. Plot each calculation as accurately as possible. <u>Show all your calculations for each planet on a separate sheet of paper</u>. You will be solving for x in the equation.

$$\frac{\textit{Distance of Pluto from Sun (in A.U.)}}{\textit{100 yards or meters}} = \frac{\textit{Distance of each planet from the Sun (in A.U.)}}{x}$$

Planet	Average Distance (AU)
Mercury	0.39
Venus	0.72
Earth	1.00
Mars	1.52
Jupiter	5.20
Saturn	9.54
Uranus	19.18
Neptune	30.06
Pluto	39.44

Extending Your Knowledge

1. If a hypothetical planet were located halfway between Uranus and Neptune, where would it be located on your scaled soccer field? Show your calculations.
2. How much farther is Neptune from the Sun than Uranus? Express your answer as a percentage.
3. The closest stars to Earth, besides the Sun, are Alpha, Beta and Proxima Centauri. They are 4.3 light years away. (a) How many miles away from Earth are these stars? Express your answer in scientific notation. (b) If this star system were a planet orbiting the Sun, what would be its period? For (b) use Kepler's Third Law, $P^2 = R^3$ where P is the orbital period expressed in years and R is the semi-major axis expressed in astronomical units (AU). Your answer in (a) is the semi-major axis. It needs to be converted to AU.
4. The Titus-Bode Law is an empirical formulation used by early modern astronomers to approximate a planet's distance from the Sun even if the planet was undiscovered. The empirical formulation works as follows: consider the sequence (0, 0.30, 0.60, 1.20,....). Add to each number in the geometrical sequence the number 0.40 A.U. to get the planet's distance from the Sun. For Mercury, add 0.40 A.U. to 0, i.e. 0 + 0.40 A.U. = 0.40 A.U. This is the distance of Mercury from the Sun rounded off. For Venus add 0.30 to 0.40 A.U. to get 0.70 A.U., the rounded off distance of Venus from the Sun.
   a) Using the Titus-Bode Law predict where you would find the nine planets in our Solar System by completing the geometrical sequence and the addition.
   b) Using the two extra copies of your scaled soccer field, cut and tape them together so

that the goal lines overlap. Plot on this two soccer field paper the calculations from the Titus-Bode formulation of the planet distances from the Sun. You will have to convert these values to yards or meters before plotting. Again, feel free to use color and relative sizes on this plot. Lay this plot alongside your first plot. Comment on any similarities and differences. Can you see how early modern astronomers used this empirical tool to hunt for new planets?

c) Where would you expect to find the tenth planet using the Titus-Bode formulation?

PHOTOGRAPHING THE NIGHT SKY

Challenge

Conduct a study of celestial objects, such as constellations, bright comets, meteor showers, planets and aurorae, by photographing the objects with a 35mm camera. Prepare a slide show to present your findings about the celestial objects in your study.

(Caution: Do not include the sun in your observations without approved eye protection.)

Instructions

1. Place a 35mm camera with a standard lens on a tripod. (No telephoto lens, telescope or motor drive is necessary.)
2. Take photographs of the celestial objects using films such as Ektachrome 200 or Ektachrome 400. This will produce positive color slides that can be viewed easily with an inexpensive color slide viewer. Experiment with your exposures until satisfactory slides are obtained. (See the information section for helpful hints.)
3. Collect data for your study of celestial objects by preparing a series of slides on a topic. Four examples are: (a) planetary motion against a background of stars, (b) life history (age and color) of stars in a given constellation or area of the sky, (c) comet motion against a background of stars or (d) meteor activity for a specified time and period.
4. Keep accurate records of dates, times and other information that will enhance your study.
5. Use multimedia and technology resources to add to your knowledge and understanding of these celestial objects.
6. Prepare a slide show that will present your findings to an audience, such as your science class. Your slide show will be evaluated by how completely and accurately you meet your challenge.

Information

1. Take photographs of constellations, planets, bright comets and aurorae with a setting of f/2.5 for 20 seconds with film, such as Ektachrome 200 or 400.
2. Take photographs of meteor showers with a setting of f/8 for several minutes with film, such as Ektachrome 200 or 400.

Using a 35mm camera, as described above, will produce little distortion from the earth's rotations. The colored slides will allow you to detect blue, white and red stars that your eye cannot easily detect. With the colored slide film, you can project these stars on a screen.

SOLAR RADIATION

Challenge

Determine the insolation (incoming solar radiation) received at your latitude for each of the seasons of the year and design a house that will effectively use the insolation.

Instructions

1. Use multimedia and technology resources to determine the tilt of the earth and therefore, the angle of the incoming solar radiation for each season of the year, your precise latitude and sunrise and sunset times. (The tilt of the earth is built into most globes.)
2. Complete an investigation, using a light source, such as a 300 watt spot light, 300 watt flood lamp, or the lamp of an overhead projector, a globe of the earth, and a light meter with a flat voltaic sensor to quantitatively measure insolation at each of the seasons. Place the flat voltaic sensor at your latitude on the globe. (A black background behind the globe will prevent scattered light and give more accurate results.) Adjust the light meter or move the light source until you get a full-scale deflection on the light

meter. This will simulate a reading found in nature.

3. Rotate the globe and take a reading at every hour between sunrise and sunset. (If this is not possible, the data will need to be taken at the same "time" each day, such as noon.) This procedure must be repeated with the globe oriented to represent each season of the year.
4. Prepare a graph to portray the data obtained about the insolation at each of the seasons. Use a key to specify the season represented in each set of data.
5. Design a solar house that will effectively use the insolation at all seasons of the year. You may want to include other scientific principles such as the green house effect or insulation components.

THE CROSS STAFF FOR DATA COLLECTING

Challenge

Build and use a cross staff to collect data about the location of celestial objects. Use the data to prepare scaled drawings to share with an audience.

Instructions

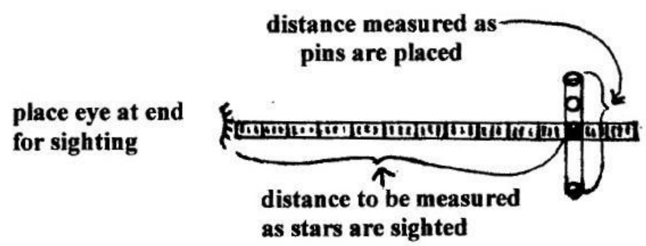
1. Observe and sketch from memory a group of celestial objects, such as the circumpolar constellations.
2. Build a cross staff (See: Building Specification.) and observe the same group of celestial objects that you used in your original sketch. Take measurements to determine the angular separation that occurs between objects in the group (See: Calculating Angular Separation.). Each object must be included in at least two separate measurements to make a scaled drawing.
3. Make a scaled drawing of the celestial objects.
4. Compare the sketch and scaled drawing for accuracy and usefulness. (Caution: Do no include the sun as a celestial object. Irreparable harm to the eyes can occur.)
5. Prepare a set of scaled drawings for use by younger children (lower grade level) to use for their study of constellations.

Option

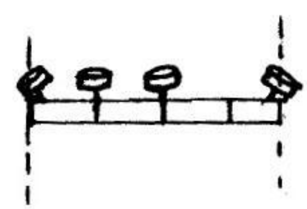
Make a study using a scaled drawing of angular separation where objects in a group are changing their relative locations over rather brief periods, such as the moon or planets found within a constellation. Include the time on each scaled drawing and prepare a sequence of the drawings for a period of time appropriate for the group of celestial objects studied. Share the sequence of scaled drawings with an audience, such as your science class. Your product will be evaluated by how accurately you build and use the cross staff and how neatly and accurately you complete your scaled drawings.

Building Specification

1. Obtain two pieces of wood, such as half round (White pine is a better material), one piece 60cm long and the other 10cm long; one rubber band (short and wide); and four push pins with white spherical tops.
2. Join the two pieces of half round with a rubber band so their flat sides are together and the short piece is on top. Place them at right angles to one another. (See below.)

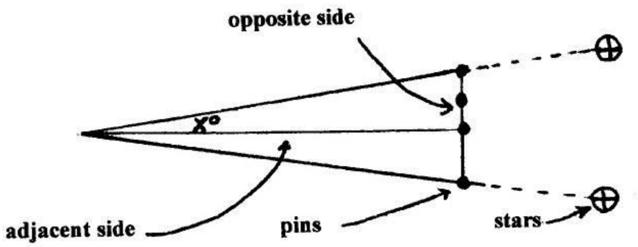


3. At each end of the short piece, place a pin at an angle so that the head of the pin is precisely over the end of the piece. The third pin is placed in the center of the small piece and the fourth pin is placed halfway between the center pin and one of the outer pins. (See below.)



Calculating Angular Separation

1. Sight along the long piece and slide the short piece until two of the pinheads cover two stars. Use trigonometry to calculate the separation. (See below.)



2. The two outer pins can be used for large angles of separation. The angular separation of the stars is twice as great as x°. Smaller angles can be measured by using the outer pin and the center pin. In this case, the angular separation is x°. Even smaller angles can be measured by using the central pin and the fourth pin.
3. A meter stick's scale can be placed on the flat surface of the long piece to make measurements easier and faster.

THE GREEN HOUSE EFFECT ON EARTH AND IN SPACE

Challenge

Investigate the green house effect and relate the data to the climate on earth and in space. Use the data from your investigation and research information to develop your own position on the course of action that should to be taken by the population of the Earth.

Instructions

1. Find out the average temperature of the earth for the past 130 years.
2. Determine the average temperature variations for the past 450,000 years. Relate this to climatic changes observed on the earth.
3. Investigate the causes of the green house effect by techniques, such as the testing of changes in temperature observed in water and gases of the atmosphere of the earth in containers that are closed with transparent covers, such as plastic wrap or sheets of glass, compared to containers that are left open (no cover) when subjected to solar radiation or simulated solar radiation, such as an incandescent lamp.
4. Relate the components of the earth and its atmosphere to the materials in the investigation that caused the green house effect.
5. Determine what the space probes discovered about the atmospheres on planets, such as Venus and Mars. Use your research data to account for the temperatures observed on the planets.
6. Expand your knowledge about the green house effect and global warming.
7. Write a position paper on some aspect of the green house effect and consequent global warming, such as:

   The Need for Concern about the Global Warming

   or

   Recommended Changes in Our Lifestyle to Prevent Global Warming.

   The evaluation of the paper will be based on how thoroughly and accurately scientific concepts and data are used.
8. Research how weather has changed in two areas of the world (your own country and your epal's), and with an epal, compile your information together into one world report.

SATURN, "JEWEL OF THE SOLAR SYSTEM"

Purpose: To aid students in understanding the size of Saturn, its rings, and large moon Titan in comparison with the Earth, and the appearance of Saturn and its rings as seen from the Earth.

The scale model Saturn will be a 3-D model of Saturn and its rings, with the option of adding the moon Titan to the model. A scale model "Earth" is also included for comparison with the model Saturn. The scale factor is 1 inch in the model represents 40,000 km in the real solar system. Sizes in the table are all given in terms of diameter and distances are from the center of Saturn (with the exception of the distance to the inner edge of the ring plane which is from the cloud tops).

A 3-inch diameter ball represents Saturn and transparency film covered with a thin layer of talcum powder represents the rings. The thickness of the rings is actually too small to see on this scale, but the almost paper thin transparency film is a good approximation. Part of the intention behind using the transparency film is that it can represent empty space. The talc represents the actual particles out of which the rings are made. "Gaps" in the rings can also be shown on the film by removing the talc from portions of the film in circles. In addition, a flashlight can be used to show how well the "rings" reflect light when it shines on them. The relative appearance of the rings of Saturn at different viewing geometries can also be easily demonstrated by placing the model in front of an overhead projector, tilting it at different angles, and observing its shadow.

You will need (for each model Saturn):

1. a copy of the Table of Sizes and Distances
2. 3 inch Styrofoam ball
3. 1 sheet of transparency film
4. orange and yellow markers
5. tooth picks
6. small candy about 1/3 inch in diameter. An M&M is close enough.
7. talcum powder
8. ruler
9. scissors
10. transparent tape
11. exact-o knife (1 for the teacher to use)
12. a compass for drawing circles
13. an overhead projector and/or flashlight
14. a peppercorn (optional)
15. string (optional)

Time requirement: 1 to 1 1/2 hours. At least 2 for older students making their own calculations.

Instructions

1) Using the compass (replace the pencil with a narrow tipped marker or felt tip pen) centered on the transparency film draw an inner circle with a radius of 1 2/3 inches (3 1/3 inches in diameter). Next draw an outer circle also centered on the transparency film 3.5 inches in radius (7 inches in diameter). For younger students you may wish to use a template and photocopy the rings onto the transparency for the student prior to the lab, or have the students trace the template.
2) Cut out the center and the outer edge leaving only a ring of transparency film between your two circles. (Here a teacher may need to make a small cut with the exact-o knife into the center of the transparency film so that the student can use scissors to cut out the center circle without cutting into the ring.)
3) Take the Styrofoam ball and make sure it will fit inside the ring, If not, cut away additional material from the inside of the ring until the ball will fit with a small gap all around.
4) Take the talcum powder and sprinkle it on the ring.
5) Smooth the talcum powder over one side of the ring with fingertips or a paper towel. Talc can also be removed with a fingertip and/or a paper towel to show the major observed gap in the rings (the Cassini division). Older students can be asked to make the Cassini division to scale with the model in both location and width.
6) Now using the yellow and orange markers color the Styrofoam ball to look like Saturn. Try to have an image of Saturn available for the students to refer to.
7) Put toothpicks (4 to 6 equally spaced) around the "equator" of your Model Saturn. The placing of the toothpicks is very critical; they all must be in the same plane or a "warped" ring will be produced. I recommend lightly drawing the equator in, or that marks are made on the ball showing the student where to place the toothpicks.
8) Place the ring on the toothpicks. Make sure all of the toothpicks are in the same plane (or at least close). Tape the ring onto the toothpicks with transparent tape on the side without the talcum powder. The talc may need to be re-applied after this step.
9) The small candy (a blue M&M will do nicely) represents the Earth. Compare the size of this scale Earth with the scale model Saturn.
10) Turn down the lights and point a flashlight at the model Saturn. Turn the model so the rings are on edge to the students, and are facing the students. Discuss why the rings of Saturn are sometimes very visible from the Earth and why they seem to disappear at other times. (Alternatively, an overhead projector can be used to project a silhouette of the model on the wall or a screen. The effect will be very visible for the entire class.)
11) Titan, the largest moon of Saturn, is about the size of a peppercorn on this scale. (Titan is bigger than the planet Mercury). Use a peppercorn to represent Titan. A red or pink peppercorn can be used to approximate the orange color of Titan. (Red peppercorns can be very fragile, so plan to have extra available.)

12) Measure the string to 30 inches. Titan is 30 inches from the *center* of the scale model Saturn and orbits in the same plane as the rings. You can attach one end of the string to the inner edge of the ring plane, but be sure to cut off the 1 2/3 inches that represent the distance from the center of Saturn to the inner edge of the rings. Alternatively, place the string on a table and Put the model Saturn on one end of string. This is easier, but may give the misconception that the orbital plane of Titan is not in the same plane as the rings.
13) Now stretch out the string until it is straight and place the peppercorn on the other end. You now have a scale model of Saturn AND its largest satellite. For reference, the tiny moon Mimas is about 1 inch farther away from Saturn than the outer edge of the rings and is 1/100th of an inch across on this scale (smaller than a grain of salt).

Suggestions for teaching this activity

Younger students

- Use the measuring as a math activity. Have students make their own measurements. You may also wish to have the students make relative size determinations. (Saturn is about 10 times wider (diameter) than the Earth, the rings are about half as wide as Saturn, and so forth.)
- Let each student make their own scale model Saturn to take home and show their parents, but still have them work together in small groups to make their models.
- Display the Saturn models in your classroom.
- The real Saturn is less dense than water, which means that if you had a tank of water big enough (which is of course impossible) Saturn would float. Try floating one of the Styrofoam balls in water (or a completed model, but the talc will wash off the ring) and tell your students about this fun fact.
- If you use M&M's or other candy for the scale Earth(s), pre-sort the candies for the color you wish to use **before** the activity. Otherwise, the students may pay more attention to the candy than the activity.

Older Students

- Give the students the table in this activity with only the first two columns filled out and the scale factor. (Alternatively, you can give them the 3 inch measurement for the model Saturn and have them determine the scale factor.) Have the students fill out the rest of the table. You can have them suggest items that can be used to represent the Earth and Titan in this activity instead of telling them the items I have suggested.
- Let the students examine the model Saturn with the flashlight in small groups. Have them determine in their groups why the rings sometimes seem to disappear when viewed from the Earth.
- Have the students look up the particle sizes in the rings. For their scale model are the talc particles a reasonable size? You might have the students compare the size of ring particles with the Saturn's moon Mimas (the size of a speck of dust in the model).
- Saturn is 1,400,000,000 km away from the Sun. Have your students figure out how far away the Sun would be in their model.

It probably isn't necessary for each student to make his or her own model Saturn. If you separate your students into small groups to calculate the scale factors, you can then have each group work together to build their own scale models based on their calculations. You can even make it a 2-day activity and have them bring something from home to represent the size of Earth and Titan.

ESTIMATING CLOUD COVER

This activity is from the GLOBE Program. To learn more about GLOBE and how to join the program, visit the web site www.globe.gov.

Background

Even experienced observers have difficulty estimating cloud cover. This seems to derive, in part, from our tendency to underestimate the open space between objects in comparison to the space occupied by the objects themselves, in this case the clouds. Students have an opportunity to experience this perceptual bias themselves, to reflect on its consequences for their scientific work, and to devise strategies to improve their ability to estimate cloud cover.

What To Do and How To Do It

Introduce students to the idea of observing and quantifying cloud cover. Explain that they will simulate cloud cover using construction paper and estimate the amount of cloud cover represented by white scraps of paper on a blue background. Demonstrate the procedures covered in steps 3 - 6 below so that students understand how to proceed.

You may review the Cloud Cover Protocol with students before doing this learning activity or use the activity as a first step in presenting the protocol to students. Step 7 below requires you to explain the classification categories that are used – no clouds, clear, isolated, scattered, broken, and overcast.

1. Organize students into pairs.

2. Provide each pair with the necessary materials:
   - one sheet of light blue construction paper
   - one sheet of white construction paper divided into 10 equal segments
   - GLOBE Science Log
   - glue stick, glue, or tape

3. Have each student pair choose a percentage of cloud cover that they wish to represent. They must choose a multiple of 10% (i.e. 20%, 30%, 60%, etc. not 5% or 95%). They should not reveal the percentage they have chosen to anyone else.

4. Have each pair cut their white paper so that it represents the percentage of cloud cover they have chosen. For example, if they have chosen 30%, they should cut out 30% of their white piece of paper and recycle the remaining 70%. Students should then tear their white paper into irregular shapes to represent clouds.

5. Have students paste or tape the cloud pieces onto the blue paper, taking care not to overlap the pieces of white paper. On the back of the blue paper, record the percentage of cloud cover.

6. Have students take turns visiting each others' simulations and estimating the percentage of cloud cover. For each simulation they should classify the sky as clear (0-10%), isolated (10-25%), scattered (25-50%), broken (50-90%), or overcast (>90%). They should then record their estimates in their notebooks, using a table similar to that shown below.

Name	Estimated %	Classification
Juan and Alice	40%	scattered
Jon and Jose	70%	broken

7. When students complete their estimates of cloud cover, create a table on the board to compare their estimates with the actual percentages and classifications

8. Discuss with the students the accuracy of their estimates and consider the following questions:

- Which were more accurate -- the percentage estimates or the classifications?
- Where did the greatest errors occur?
- Can students come up with a quantitative measure of their collective accuracy?
- Does the class have a tendency to overestimate or underestimate cloud cover?
- What factors influenced the accuracy of the estimates (e.g. size of the clouds, clustering of the clouds in one part of the sky, the percentage of sky that was covered)?
- Do students feel that making these estimates is something they have a knack for, or is it something that they can learn?
- Where else might such spatial estimation skills be valuable?
- Which cloud classifications were the easiest and most difficult to identify?
- What strategies enabled students to succeed?
- What strategies might produce more accurate classifications?

OBSERVING VISIBILITY AND SKY COLOR

This activity is from the GLOBE Program. To learn more about GLOBE and how to join the program, visit the web site www.globe.gov.

Background

Why is a clear sky blue? The atmosphere consists primarily of molecules of oxygen and nitrogen. Sunlight bounces off these molecules, a process called scattering. Light with shorter wavelengths, at the blue end of the visible light spectrum, is scattered more efficiently than longer wavelengths. To an observer on the ground, this scattered light fills the entire sky and a clear sky appears blue.

However, there are also liquid and solid particles called aerosols suspended in the atmosphere. When there are relatively few aerosols, the sky appears clear. For example, a distant building or mountain peak appears clearly defined, with colors similar to what you would see if you were much closer to that distant object. On a very clear day, you would report the sky color as blue or deep blue and the sky condition as clear or unusually clear. Aerosols come from natural sources such as condensation and freezing water vapor, volcanoes, dust storms, and salt crystals evaporated from sea spray. They also come from human activities such as burning fossil fuels and biomass (e.g., wood, dung, dried leaves) and plowing or digging up soil. Aerosols are much bigger than gas molecules (they range in size from about 10-6 m (1 micron) to 10-7 m) and they scatter light from all visible wavelengths. Individual aerosols are too small to be visible to the human eye, but their presence affects the sky's appearance. As the aerosol concentration, and therefore scattering of sunlight, increases, the sky appears less blue. Haze is the visible effect of aerosols on the atmosphere; it is a qualitative condition you can observe. When aerosol concentrations are high, we say that the sky looks hazy. Aerosol concentrations can also be measured quantitatively.

Hazy skies appear pale blue or almost white. Depending on the type of aerosols present in the atmosphere, the sky may also appear brownish or yellowish. Scattering of visible light through a hazy sky affects horizontal visibility, so distant objects appear less distinct, with washed-out or distorted colors. Distant objects that are visible on a clear day may actually disappear on a hazy day. Aerosols, probably produced by urban smog, cause the haze evident in this picture of the Empire State Building in New York City.

Photograph © Forrest M. Mims III. Used by permission. May be freely reproduced with acknowledgement.

Over the past few decades, horizontal visibility has declined around the globe, on average, due to increasing aerosol concentrations. As a result, scenic vistas throughout the world have been obscured.

Teacher Preparation

In this activity, your students will carefully observe the atmosphere over a period of days and record their observations. Through these direct observations they will develop an understanding that visibility and sky color are related and that both are due to the relative presence or absence of aerosols.

The students will classify the sky color using standard categories and will represent the sky color using paints or colored pencils. They also will record the visibility based on observation of a distant object such as a mountain or a building. It is not important that they observe every day, but they should try to sample a wide range of the visibility and sky conditions that occur at your location. They should try to observe on some very clear days, on some hazy days, and on some intermediate days. After they have observed and recorded examples of very clear days, very hazy days, and various conditions in between, the class will record their observations in a summary table and see whether or not a pattern emerges that relates visibility to sky color.

Visibility

By "visibility," we mean the clarity with which objects can be viewed through the intervening atmosphere. In order to judge visibility or the clarity of the atmosphere, students need to be able to look out at a distant scene, such as a distant building or a mountain or hillside. By looking at the same scene or object every day students will gradually develop a sense of whether the day is unusually clear, clear, somewhat hazy, very hazy, or extremely hazy. Only practice, lots of different examples, and discussion will make these categories clear. (No pun intended!)

Sky Color

Students are also asked to observe, classify, and represent the sky color. They will classify the sky color using the categories listed at the bottom of the data sheet. They represent the sky color in a drawing using paints or colored pencils. They could also try using photographs or color paint chips. As they make more observations, the students will become more confident of their classifications and more skillful in drawing the sky color.

Students may notice that the sky is often a different color in different parts of the sky. Near the horizon it is typically lighter due to the presence of aerosols. The darkest part of sky can often be seen about half way between the horizon and directly overhead, in the "anti- sun" direction - that is, when you look at the sky with your shadow in front of you. Students should try to locate the darkest (bluest) color of the sky and record it.

Correlation Between Visibility and Sky Color

One of the purposes of this activity is for students to realize that on the clearest days with the highest visibility the sky is a deep blue color, while on hazy days it appears milky. Changes in visibility and sky color are both due to changes in aerosol concentrations in the atmosphere. Because aerosols scatter sunlight, high aerosol concentrations make it harder to see distant objects and make the sky appear lighter. On clear days when aerosols are low, visibility is high and the sky is deep blue. But do not TELL students this; let them discover it by pooling the class observations in the Visibility and Sky Color Summary Chart. It should be the case that most of their observations will tend to fall along the main diagonal from upper left to lower right.

What To Do and How To Do It

1. Lead students through a discussion of aerosols, visibility, and sky color. Begin by asking them what they recall about times when the sky was very hazy. How was the visibility? How did they recognize that visibility was low? What color was the sky? When did this occur? What do they think caused it?

2. Continue by asking them to recall a time when the sky was very clear. What did it look like? What color? How was the visibility through the atmosphere? When did this very clear event occur? What was the weather like at that time? What do they think caused the air to be so clear at that time?

3. If it has not already come up in discussion, discuss the role of aerosols in the creation of haze. Discuss local and regional sources of aerosols. Discuss, also, how aerosols such as dust can be transported from long distances and affect local conditions.

4. Explain that they will undertake an investigation of sky color and visibility. Introduce the Visibility and Sky Color Data Sheet and discuss how to use it. Take observations for as many days as necessary to obtain a full range of sky conditions in the data.

5. After the class has made a large number of observations, covering the entire range of sky conditions that occur in your area, bring the class together for a group discussion of the data. Engage the students in a discussion of the conditions that existed when they observed the clearest and their haziest skies. What was the weather like? What do they think accounted for the clearest and the haziest skies? When they had hazy skies, was the haze created by local, regional, or long-distance factors?

6. On the blackboard or on chart paper, create a chart similar to the Visibility and Sky Color Summary Chart shown. Invite students to contribute their data to the chart by placing a mark in the appropriate cross-classification cell to represent each of their observations.

7. When the chart has been populated with all of the student observations you should observe a diagonal trend in the data, from upper left to lower right. Ask students to explain why this trend exists. What is the common element that causes both low visibility and milky skies?

8. (Optional) Have each student or team create a "key" to help them make future observations. Select one sky color example for each level of visibility/sky color from "unusually clear" to "extremely hazy." Use these keys to standardize your observations of haze conditions. Students can continue to take observations throughout the year and note relationships to season, storms, time of day, temperature, wind direction and other conditions. Depending on students' ages, these color keys can be sky paintings, photographs, or paint color chips that can be obtained from stores that sell interior paint.

Student Preparation for Observing Visibility and Sky Color

Make these observations only on days when you can see the sky. Do not attempt to observe visibility and sky color on days that are overcast. For each day that you make an observation, record the date, the local time, your estimate of the visibility and your estimate of the sky color.

Both visibility and sky color are subjective classifications. That means you should expect some variation among observers and changes in your own classifications as you gain experience. As you gain experience in observing the atmosphere and the sky you may change your mind about some of your initial classifications. You may decide that what you originally classified as a deep blue sky you now consider to be merely "blue." Or, you may decide that what you thought was "somewhat hazy" was really "very hazy." Do not worry about this and do not go back and change your original observations. You can expect your skill in classifying to evolve and change. Gradually, you should gain confidence in your ability to classify consistently.

1. Estimate the Visibility – Select some distant object - a mountain range, a building, or other object several kilometers away. Use this object as your "reference object" to judge visibility every day you make an observation. Take note of how distinctly you can see it and select one of the visibility categories below and record it on the Visibility and Sky Color Data Sheet.

Unusually clear

Clear

Somewhat hazy

Very hazy

Extremely hazy

2. Observe the Sky Color – Now look at the sky and find the part of it that is the darkest color. When you do this activity, be sure not to look directly at the sun even if it is partially obscured by clouds. Select a category for the sky color from the list below and record it on the Visibility and Sky Color Data Sheet.

Deep blue

Blue

Light blue

Pale blue

Milky

3. Paint or draw with colored pencils your best representation of the sky color in the "picture" box. You can also use paint color chips or photographs to represent sky color.

Questions for Understanding

1. When you see blue skies, what other weather conditions are likely to exist? What else would you observe on very clear days?

2. Are you aware of any daily patterns in sky color and visibility in your location? Is it usually hazier at certain times of day? What causes this?

3. How are sky color and haze related to weather?

4. Are sky color and haze at your location related to the amount of wind and the wind direction? If so, why?

4. Are sky color and haze at your location related to the time of the year? That is, are there seasonal patterns in your data?

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