SUNSPOTS Lesson Plan

Topic Area:
The history of sunspot study, our current understanding, and research into how sunspots are connected to other solar phenomena.

Key Questions:
• How have humans studied and understood sunspots throughout history?
• What do we currently know about sunspots and their effect on the earth?
• Do visible sunspots seen on the solar disk correlate with the areas of active regions seen in x-ray images?

Objectives/Purpose:
• Describe how ancient and modern cultures have studied and understood sunspots.
• Students can observe the sun safely using simple equipment.
• Discuss and question why and how sunspots and related solar activity affect us on the earth.
• Measure and compare the areas of sunspots and x-ray emitting regions using graphs to show or disprove a correlation.
• Present the results and determinations for peer review and discuss the quality of research done by students in class.

Grade Levels:
Most appropriate for high school, grades 9-11

Time Requirements:
• Total class time is 5 class periods; about 2 hours teacher preparation time, plus 1/2 hr to assemble observing apparatus.
• History section: 30 minutes teacher preparation and Xeroxing. Approx. 1 period for students to study the lesson pages and answer questions on the worksheet. Half a class period for solar observation.
• Modern Research Section: 30 minutes teacher preparation. 1.5 class periods for students to study the pages and answer study questions, prepare research proposal worksheet, or do jigsaw presentations.
• Activity section: 1 hour for teacher preparation. 2 class periods for students to make measurements and graphs, and present results for class collaboration and/or discussion.

Key Concepts:
• Sunspots have fascinated scientists for centuries, and have more recently been recognized as part of the sun's constant activity that affects the earth's outer environment every day.
• Sunspots are regions of very dense magnetic fields that may also be associated with areas producing energetic x-rays in the sun's corona.
• If scientists can establish that events in different parts of the electromagnetic spectrum are correlated, this may help them understand the transfer of energy that heats the corona.

Guiding Documents:
National Science Education Standards (NSES) Grades 9-12
http://www.nap.edu/readingroom/books/nses/html/6e.html
• Science as inquiry
• Physical Science: Interactions of energy and matter
• Earth and Space: Energy in the earth system
• Perspectives: Natural and Human-induced hazards
• History and Nature of Science
AAAS (Project 2061 Benchmarks for Science Literacy)
http://www.project2061.org/tools/benchol/bolframe.html
- Scientific Enterprise
- Forces of Nature
- Patterns and Relationships
- Computation and Estimation
- Communication Skills

National Math Standards (NCTM)
http://www.illuminations.nctm.org/standards/index.html
- Patterns, Functions, and Algebra
- Data Analysis
- Measurement
- Geometry from an Algebraic Perspective

Materials:
1. Internet connected computer with WWW browser program (e.g. Netscape, Internet Explorer): 1 per 1-3 students. OR computers with browsers, CD-ROM drive and Sunspots CD.
2. Browsers should be Java-enabled, and optimally have RealMedia and QuickTime player plug-ins. For help with installing plug-ins, see the lesson's help page.
3. Student worksheets: 1 copy per student for those worksheets desired
   a. Dawn of Sun Science -History section
   b. Researcher Qualifications -Modern Research section
   c. Solar Research Proposal -Modern research section
   d. Research Data Log -Activity section
4. Graphing Sheets: 1 per student for those sheets used
   a. Sunspot area vs. date
   b. X-ray active area vs. date
   c. X-ray vs. Sunspot area
   d. Plain graph paper if students are to draw and label their own axes
5. For sunspots observations
   a. Binoculars or a telescope
   b. Tripod or other stable mount with angle adjustment
   c. Cardboard, duct tape, and/or cloth for shrouding the projection area
   d. Flat projection surface with paper for drawing, if desired

Background Information:
- Background content summaries are provided as HTML documents that may be printed out.
  1. Background I: History and Modern Research
  2. Background II: Research Activity and Results
- Please read the lesson pages themselves, as they support the main points about solar science with careful explanations and many illustrations. This provides a context for the discussion of sunspots, which arise from quite complex causes. The lesson is in the folder marked "SUNSPOTS" on the CD. Alternatively, it can be accessed with the URL:
  http://cse.ssl.berkeley.edu/segwayed/lessons/sunspots/index.html

Preparation:
Student prerequisites
- Reading at an 8th grade level (glossary of new terms provided)
- Ability to plot points on a graph
- Ability to navigate a Web site in a browser

Computer set up
- Test a typical browser setup for Java functionality and make sure the RealMedia clips and QuickTime movie play. Get help from a technician for upgrades or installations if necessary. All software should be available through the help page or from your CD.
- If using a CD copy of SUNSPOTS:
  1. If possible, download the folder called "SUNSPOTS" with the lesson pages onto a local (i.e. your school's) server, and set up bookmarks on the students' browsers to open the lesson.
  2. Otherwise, drag-and-drop the lesson folder to the hard drive of each student computer and make appropriate bookmark.
- If using the lesson directly from the Web, check on the download times for some pages, to estimate the pace students can expect. Some alternatives for low-bandwidth sites are described below, in Contingency Management.

General Preparation
- Instructors may wish to pick and choose parts to cover or emphasize, according to local frameworks and time available. Students doing the interactive research activity should cover the "Modern Research" section ahead of time.
- Decide which parts of the lesson and supporting materials will be completed on each day.
- If students will work in teams, determine groupings and assignments. Measuring all 26 pairs of images is tedious for a single person; divide the measuring of the images among group members, or assign a different subset to each individual.
- Make assignment sheets, listing the steps each student/group should complete, if you wish.
- Print and copy student worksheets, and any parts of the lesson you wish to have students read off line or before going to computers.
- Assemble apparatus for sunspot viewing, using the materials above and guided by the illustrations on page History 4. If possible, do a dry run, setting up the equipment and getting the solar image on the viewing surface.
- Make up a lesson schedule for each class, according to the activities chosen and the length and blocking of class periods. Refer to Procedure for estimated times.

Procedure:
Student activities are numbered.
- Introduce the lesson and the general subject of solar science. Hand out any paper materials such as assignment sheets, worksheets, etc.
- Discuss the class's current understandings of solar science and sunspots, using some or all of the discussion questions below. Divide the class into working groups if appropriate. (10-20 minutes)

History section
1. At the computers, have students view the History section and complete the study questions. (30 minutes)
2. Sunspot viewing. This depends on weather conditions, so it may have to be done on another day. It can be repeated in about 20 minutes at intervals of several days to show the changes in sunspots. (45 minutes)
   ? Assign teams to make sunspot observation drawings. Have students set up apparatus, and help them get the sun in view, so that its image appears on their screen. Demonstrate as needed.
   ? Have students record the location, shape and number of sunspots. They should label their drawings with date and time. Never look at the sun, either directly or through binoculars!
Modern Research

- Discuss and share general knowledge of the electromagnetic (EM) spectrum of the sun, solar phenomena and space weather using the discussion questions (15 minutes)

1. At the computers, students should read the Modern Research section and play the interviews, answering the study questions if desired. This section is longer and more dense. One option is to assign a section of material to each group, to master and teach the class, jigsaw fashion (50 minutes).
2. Afterward, students prepare their own ideas for new solar research using the proposal worksheet. This is also an opportunity for doing Web research and class discussion on their ideas, if desired. (30 minutes or longer)
3. If the section has been covered by jigsaw groups, have groups present their new knowledge to the class using the Web pages or their own visual aids. (60 minutes)

Research Activity

- Have students view the first page of the Activity section and the QuickTime movies. Discuss what the movies show and students' view of what is happening, in light of the sections on the sun's structure. (15 minutes)
- Introduce the motivation for the activity and the concept of correlation. Illustrate the idea of establishing correlation graphically with a real-life example, like the fact that frosts correlate with colder weather, or the high correlation between smoking and lung cancer. If the class will not be graphing the areas vs. time, you may want to simulate this step on a blackboard or overhead so students can try predicting what their plots might look like. (15 minutes)
- Assign the subset of the images or image pairs to be measured by each student or group.
  1. At the Computers have students read the rest of the Activity pages, starting with Activity 2 (Measure Image Areas) and practice using the Java applet first. (30 minutes)
  2. Students then use the applet to measure image areas and record their measurements. They will plot their measurements using the computer and/or manually on sheets provided, or on their own graph paper. (50 minutes)
  3. Students or groups discuss their findings and present them to the group for instructor/peer evaluation and discussion. (50 minutes)

Discussion:

General/History

- What is the sun made of? How big is it?
- What is the sun like inside?
- What do you think ancient cultures, e.g. Egyptians, Mayan/Aztec, Greco-Roman, knew about the sun?
- Did they study the sun?
- Why would they think it was important? Eskimos, for instance, do not have an agrarian society, and have not produced the kind of elaborate sun-tracking schemes that the Mayans and Incas had for timing their planting and harvesting.
- When do you think sunspots were discovered?
- How would early scientists have studied the sun?
- What instruments do you think they used?

Modern Research

You may wish to start with an image of the sun from a textbook or some familiar context like a magazine, asking students questions that hinge on their understanding of the image.

- What is the electromagnetic (EM) spectrum? In what parts of the EM spectrum does the sun emit light?
• Do you think the sun is changing? If students think the sun is changing, talk about what changes they know of and their time periods, e.g. ~10 billion years for burning up all its hydrogen, but ~28 days to rotate once, and ~1 day to emit a coronal mass ejection (CME).
• Does the sun have a magnetic field?
• What do you think causes sunspots? What are they?
• How do you think what happens on the sun might affect the earth: each year? Each week? Each day?

Research Activity
It may be that different students' or groups' resulting graphs look different. Remember that a straight line is not necessarily expected, but the class should reach some consensus on whether there is some correlation between the 2 quantities: a linear, or curved, but at least continuous functional relationship. This can be an opportunity to discuss science processes and the difference between scatter in the data and systematic errors. Discuss some possible reasons for differences among students' or groups' results:
• Different colors were included in the x-ray areas
• The visible light sunspot areas have far fewer pixels, and so are much more sensitive to small differences--1 pixel more or less may be quite significant.
• The exact scale of the x-ray image color scheme in counts/pixel is unknown. It may even be logarithmic. What would that look like on linear paper?
• Compare the depth of the x-ray corona, which extends far out into space, with the small, finite thickness of the photosphere where sunspots are located. The x-ray disturbances seen in the images may have shapes and sizes that vary rapidly, especially near the edge of the solar disk.
• Is the pixel size on the screen a convenient unit of measurement?

Contingency Management:

• Printed versions: The History and Modern Research sections can be printed from the browser and photocopied if students' access to computers is limited. In this case the RealMedia interviews are not available, but they appear excerpted in the text, and instructors may also show the images and RealMedia on a computer with a projector system.
• Parallel groups: If the number of computers is fewer than 1 per 3 students, some students may be engaged in writing activities or preparing presentations while others are at the computers.
• Class management for the research activity: It's important not to let students get bogged down here, and it can happen. Make sure everyone practices using the Java applet. Self-debugging will be important. You may want to halt the class for discussion during this time if several groups seem to be having similar difficulties. Keep an eye out for students who are losing data, not seeing points in the values lists, or points on their plots. See Background II document.
• Printing Activity Results: Due to the nature of Java applets, printing values tables and graphs can only be done by taking a screen "snapshot." This can be done on many systems using a "Print Scrn" key if a printer is available. If not, the same keystroke will often save the screen in a bitmap buffer for cropping in an image-handling program.

Assessment:
The following are included with this Guide:
• Dawn of Sun Science answer key
• Solar Scientist Qualifications answer key
• Student research proposal rubric. Proposals might include:
  ? Need for research on the selected problem or question
  ? Determining appropriate observations to provide the needed data
  ? Planning the sequence of the observations
  ? Observation and data collection
  ? Representing the data--how it will be manipulated in images and/or graphs.
? Analysis: how will analysis proceed to answer the research question?

- Students present their research results from the Activity section and compare them to those of other teams or students. Presentations should include conclusions drawn from analysis of their graphics, and an analysis of possible sources of error in their processes.
- Class collaboration and discussion may be used to develop a mock journal review for research results and appropriate rubric.
- A paper and pencil test with multiple choice and short-answer questions is also available in this guide.

? SUNSPOTS Pre Test / SUNSPOTS Post Test
? Pre-Post Test Answer Key

Extensions:
There are numerous opportunities for students to do hands-on activities that illustrate the physics of sunspots and help them visualize what is described in these pages. Some suggestions:

- Making electromagnets. It's never too early to introduce or reinforce the relationship between electricity and magnetism. Any current of moving electrons, like a wire whose ends are connected to the terminals of a battery, produces a magnetic field that can be sensed with a compass.
  - Field lines for a straight wire are circles orthogonal to, and concentric with, the wire.
  - If a current-carrying wire is wound into a coil, the magnetic field is a dipole, and field lines loop from north to south like the protruding solar flux loops that create sunspots.
  - Transfer some charge to a metal ring, and place the ring on a spinning platform, like a record turntable. This also produces a dipole field, albeit a very weak one, given the currents involved.

- Use a strong U-magnet and iron filings to create visible models of magnetic flux loops. Placing a sheet of paper over the ends of the U magnet, students can pile iron filings above and observe the dipole arc that forms between the two poles. The filings form footprints around the ends that resemble the sunspot penumbra as well.

- Convection demonstration using instant miso soup in Pyrex or heavy glass containers and hairdryer. Apply the heat from the hair dryer underneath to set up convection, simulating the transfer of heat from the radiation zone to the photosphere by the convection zone. Question: Why is the motion of the fluid ordered into circulating currents? Why is this an efficient way to transfer heat? (It bypasses heat exchange between the particles within the flow, carrying heat directly to the surface, where there is a phase difference from liquid to vapor.)

- If you are using the Research Proposal worksheet, students can do research on the Web to get ideas and details for designing investigations. Some excellent Web sites on solar science and space environments are listed in the bibliography page. Here are more examples:
  - NASA's Sun-Earth Connection Education Forum (SECEF)
    http://sunearth.ssl.berkeley.edu/
  - Astronomy in Your Face: The Sun
    http://www.sorgeweb.com/astronomy/solar_system/sun.htm
  - Graphing Stratospheric Ozone:
    http://cse.ssl.berkeley.edu/segwayed/lessons/ozone/graphing.html
    a lesson about graphing, ozone chemistry, and possible ecological consequences.

Curriculum Coordinates (optional):

Social Sciences -

- The Center for Archaeoastronomy: http://www.wam.umd.edu/~tlaloc/archastro/
- Lords of the Earth: http://www.mayalords.org, Archaeoastronomy and Anthropology of the Americas
- Great Moments in the History of Solar Physics
  http://www.hao.ucar.edu/public/education/sp/great_moments.html
• See the lesson's bibliography page for more printed and Internet resources.

Mathematics – The Cartesian representation of the algebraic form for straight lines, least squares fit to a straight line, and simple statistics are appropriate for coincident work in mathematics classes.

Meeting Individual Needs:
• This lesson may be appropriate for advanced students in upper middle school. Parts may be applicable for lower middle grades. This lesson was successfully tested in summer courses for 8th-9th-grade transition students.
• This lesson contains an applet that requires controlled use of a mouse or other tracking device, which may be difficult for students with motor-control disabilities.
• The history section contains references to science in Mesoamerican, ancient Middle Eastern, and Chinese cultures. These might serve as subjects for further research and writing projects for language arts development.