Observing the Sun: Adapting the Helioviewer Data Tool for Educational Use

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Abstract: The Sun is our closest star and Heliophysics—the study of the Sun—offers dynamic and compelling phenomena for students to learn math, physics, chemistry, and biology in a systems-science approach. Innovations in NASA spacecraft data and digital tools provide increasingly authentic opportunities for educators to engage learners actively in scientific practices around solar phenomena such as sunspots and solar eclipses. This paper will present the instructional design case of the adaptation of NASA’s Helioviewer data tool into a version—the “Student Helioviewer”—for use by learners in middle and high school. We first connect solar phenomena to learning opportunities via educational standards and then describe the design of the “Student Helioviewer” through a brief description of adaptations and a comparison of the two versions of the Helioviewer data tool.

Adapting Data Tools for Learners

Scientific data visualizations are increasingly a core practice of modern computational science across all domains—and particularly relevant for solar physics where one NASA satellite alone, the Solar Dynamics Observatory, currently generates more than a terabyte of image data per day. With recent science education standards emphasizing student engagement in science practices (NRC, 2012), scientific data and visualizations will only increase in their availability and use for K-12 science instruction. Key to delivering on successful learning outcomes is the ability to design data tools that enable active student engagement in scientific practices, like analyzing and interpreting data, while remaining engaging and accessible.

Learning with Solar Phenomena

All students will learn about the Sun sometime in their formal education experience. The Next Generation Science Standards (NGSS Lead States, 2013), which were developed from the NRC’s Framework for K-12 Science Education (NRC, 2012), include standards at the Elementary (K-5) level that ask students to observe patterns of both the Sun’s motion in the sky and the seasonal brightness of sunlight over time (See Appendix A for details on standards alignment). Middle school standards include developing and using models to describe eclipses and their causes, as well as determining scale properties of the Sun and other objects in the solar system. In high school, learning goals include using, “a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate,” as well as developing, “a model based on evidence to illustrate the life span of the Sun and the role of nuclear fusion in the Sun’s core to release energy that eventually reaches Earth in the form of radiation.” Much like Earth weather, this “space weather” caused by the Sun needs to be studied, predicted, and monitored to protect astronauts, spacecraft, and power grids here on Earth. The standards for middle and high school depend on observing, measuring, and determining patterns and size scales that are often difficult for students to actively participate in directly given the distance and brightness of the Sun. These learning goals informed the criteria and constraints for the adaption of the Helioviewer—an existing online Heliophysics data tool from NASA.
The Helioviewer Data Tool

There are many different ground and space-based observatories that take images of the Sun in many different wavelengths of light—both visible and beyond. Using different wavelengths allows observation of different features and events of scientific interest on the Sun, such as sunspots and solar flares. Features and events on the Sun are measured and described by both human observers and automated feature detection algorithms. Visualizing these many different types of solar data is an important component in developing familiarity with solar phenomena, which is a fundamental starting point for more complex scientific investigations. Heliophysics data also presents a “big data” challenge in that there are huge volumes (tens of petabytes) of different types of data available from a variety of sources.

The Helioviewer Project is a response to the need to allow scientists to visualize big datasets from a variety of sources. The original target audience for this project was the scientific community. This target audience is interested in solar phenomena that occur on multiple time scales, from seconds to decades, and at multiple length scales, from a few kilometers to the size of the solar system. The Helioviewer Project has developed helioviewer.org, a web interface that allows the user to visualize the behavior of the Sun at these multiple time and length scales. It is designed to provide an efficient visualization capability for many petabytes of solar data on phones, tablets, laptop, and desktop computers. Users can select a time they are interested in, the solar phenomena or activity they want to look at, zoom in and out, pan across the image, add feature and event labels, create screenshots and movies, and share them to YouTube. Users can also use helioviewer.org to obtain the underlying science data for any solar phenomena that they are visualizing.

Figure 1 shows a typical use of helioviewer.org. The bright puff of blue-white material is an image of a coronal mass ejection (CME); such events are significant drivers of space weather events and can affect systems in space and on Earth. Shown here are images from instrumentation on two separate spacecraft. The yellow part of the screenshot is an image taken by the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory. The red and blue parts of the image correspond to images taken by two detectors that comprise part of the Large Angle Spectrometric Coronagraph (LASCO) onboard the Solar and Heliospheric Observatory (SOHO). In addition, the Sun has four markers on it indicating the positions of sunspots, and towards the bottom right the bright feature is identified via the “Saturn” label. Taken together, this image shows how multiple observational datasets from different sources can easily be viewed together to tell a dynamic story of both solar activity and the scale in relation to another planet in the solar system (Saturn).
The design of the Helioviewer.org web interface makes the assumption that the user already has some knowledge of heliophysics. This knowledge is implicit in the data selected for show in Figure 1. For example, in order to view a CME a user will need to know that CMEs are observable in LASCO, and that LASCO is an instrument onboard the SOHO spacecraft. This information is fundamental to the organization of the practice of heliophysics and is learned, often implicitly, by newcomers who intend to study in the field.

Adapting the Helioviewer for Student Learning

Adapting an existing scientific data tool for instructional use with learners is more of a practice of what to not include than what to keep. The primary goals for our design were to decrease the cognitive load for the learner, increase usability in a classroom setting, and ensure a focused interaction with the phenomena that supported middle and high school educational standards. Key to this was maintaining active engagement with solar phenomena for the learner—not simply accessing data. In the remaining sections we will detail specific aspects of the adaption of the helioviewer.org web interface, focusing on how the functionalities were adapted for the student version.

A “Phenomena First” Approach

The fundamental shift in the adaption of the Helioviewer for learners was moving from a data viewer that asks the user to select the instruments and wavelengths, to a simple menu for the user to select specific solar phenomena that they wish to observe (Figure 2). A streamlined list of solar phenomena was developed that would address the educational standards plus current event news about solar storms. These include the ability to observe and measure sunspots, flares and active regions, eruptions and CMEs, and magnetic field measurements on the Sun. Once the learner selects what they want to observe, all of the instrument and data selections are done automatically on the backend to present an optimized view of the particular phenomenon that they selected.

Measuring Size and Scale

Measurements of size and scale are important for student learning goals in middle and high school. A slider was added to make it easier to zoom in and out of the viewing window, especially for classrooms that had touchscreen tablets or interactive whiteboards (Figure 3). To make size scale comparisons more concrete, an “Earth ruler” was added to the bar ruler measurement tool (Figure 3). This gives students the option of comparing the size of an object, like a sunspot, to the size of Earth.
Streamlining Event Information

Users of helioviewer.org can toggle on “Feature and Event information” to obtain the underlying science data for any particular solar activity they are interested in. In the student version, learners maintain the ability to view key information about a solar event, like the name and classification, that give them the capacity for continued and deeper research. However, for both classroom management and to limit cognitive load, the additional direct links to external database and website searches were removed from the event information popup window (Figure 4).

Making Images and Movies

Users of helioviewer.org can make a movie that is shared directly to YouTube, an online video-sharing service. In the student version of the Helioviewer, we wanted learners to maintain the ability to generate their own images or videos of events and patterns that were important to them. However, many schools limit access to YouTube for both bandwidth and content reasons. Therefore, the “direct to YouTube” functionality was removed, while maintaining the ability for learners to “Make a movie” or “Take a picture” (Figure 5). The settings within each of these functions were also limited to lower the size of the media files that can be generated, which decreases the potential that multiple students making and downloading large video files would overload a classroom’s internet bandwidth.
The Student Helioviewer Interface

Figure 5 shows the complete and final Student Helioviewer interface and includes an image of the same solar event data as seen in Figure 1. This allows for a final comparison between the full, scientific data viewer (Fig 1) and the adapted Student Helioviewer (Fig 6). The Student Helioviewer web interface greatly decreases the cognitive load on a learner or educator opening the data tool for the first time. A persistent interface window is much smaller and limited to time and date controls and the selection of the type of solar activity or phenomena they wish to observe. A “Newest” button allows for a teacher to say, “Let’s look at the most recent view of our Sun,” which is especially useful when there is a solar storm or other activity in current events. Further details about solar activity can be toggled on, should learners wish to do further research. Finally, solar activity can be measured with simple and concrete rulers, and students are able to generate data and artifacts (images or movies) of their own observations to use as evidence. Together, these adaptations to the helioviewer.org data tool make the Sun more accessible for learners.
References


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Sun, Heliophysics, Helioviewer, Data tool, Instructional design, Solar phenomena, Big Data, Student engagement, Science and Engineering Practices, Next Generation Science Standards, NGSS

Appendix A: Connecting Heliophysics to Educational Standards

Heliophysicists study three big questions:

- What causes the Sun to vary?
- How do the Earth, the solar system, and heliosphere respond to the changes on the Sun?
- What are the impacts of the Sun on humanity?

Below are suggestions from the NASA Heliophysics Education Activation Team at Goddard Space Flight Center that align learning ideas about the Sun with specific Disciplinary Core Ideas in Earth and Space Science (ESS), Physical Science (PS), and Life Science (LS) from the Next Generation Science Standards (in parentheses):

I. Sun's impacts to humanity

i. The Sun is really big and its gravity influences all objects in the solar system. (PS2, ESS1)

ii. The Sun is active and can impact technology on Earth via space weather. (PS1, PS2, PS4, ESS2, ESS3)

iii. The Sun’s energy drives Earth’s climate, but the climate is in a delicate balance and is changing due to human activity. (PS1, PS2, PS3, LS4, ESS2, ESS3)

II. Earth's and solar system's response to the Sun

i. Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)

ii. The Sun defines the space around it, which is different from interstellar space. (PS2, ESS1, ESS2)

iii. The Sun is the primary source of light in our solar system. (PS1, PS2, PS3, PS4, ESS1)

III. Solar variability

i. The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)

ii. Energy from the Sun is created in the core and travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3)

iii. Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)