ASTRO BEAT

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WorldWide Telescope: The Universe in Your Hands

by Harry Houghton (Harvard University)

WorldWide Telescope is a free education and research tool, available as either a web-based or Windows application, that places users in an interactive, 3-dimensional visual environment to explore the mysteries of the universe.

When teaching science topics in which objects are too large or too small to observe in laboratory settings—as is the case for astrophysics—how do you convey complex and intangible relationships in a meaningful way?

Studies have shown that interactive visualization models that address common misconceptions can be powerful learning experiences. This article examines how the WorldWide Telescope (WWT) Ambassadors program has utilized the dynamic environment of the WWT platform to build meaningful representations of complex topics, and effectively address these teaching needs.

WorldWide Telescope

WorldWide Telescope (WWT) is an astronomy visualization program that offers broad access to astronomical data.

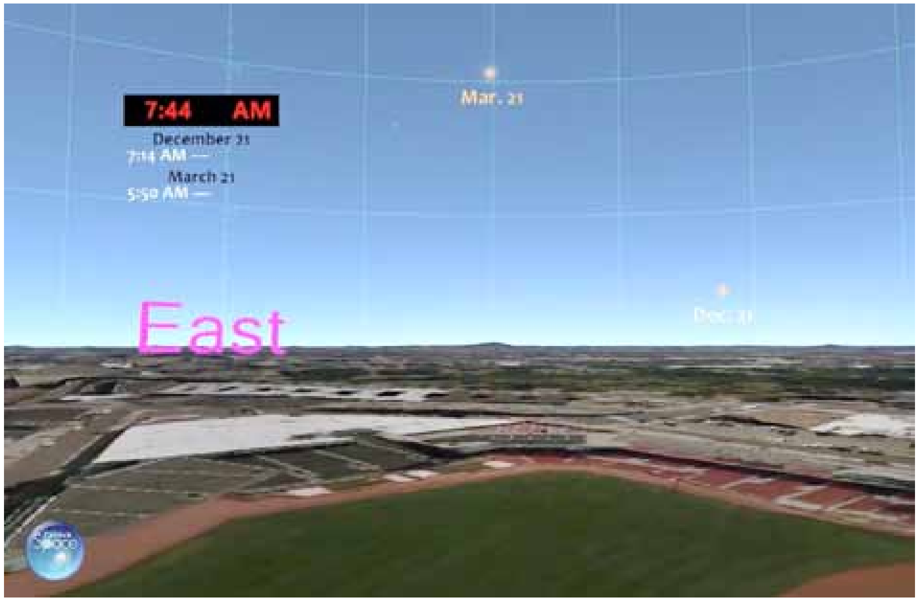

Figure 1: WWT image from the Seasons Lab. Students observe a comparison of the Sun's path through the Boston sky on March 21 vs. December 21.

This virtual observatory allows users to explore the universe across multiple representational perspectives of the same massive system. They can observe the farthest reaches of the sky from Earth, and then switch to a three-dimensional representation of the nearby universe that would be impossible to see from within the Milky Way.

Users can create and share multimedia "guided tours" to present a narrated, animated path across the cosmos. This feature is the backbone of the educational potential of WWT. Educators can create narrative tours to connect astronomy concepts with flow and accuracy. Students, too, can create their own tours to demonstrate their understanding. For all members of the classroom, WWT excites inquiry, exploration, discovery, and understanding.

WWT Ambassadors

The WWT Ambassadors (WWTA) program is run by a team of astronomers and educators at Harvard University. In the course of their work, the team has developed several curricula for K-12 science classes and introductory-level college astronomy courses that combine interactive WWT explorations and hands-on models. These curricula were designed to help novice learners visualize complex phenomena that are challenging to grasp, due to the enormous distance or time scales involved. Here, we'll look at several examples of this coursework and how they were designed. The Seasons & Moon Phases Labs were developed for middle school students, but can be adapted for older audiences.

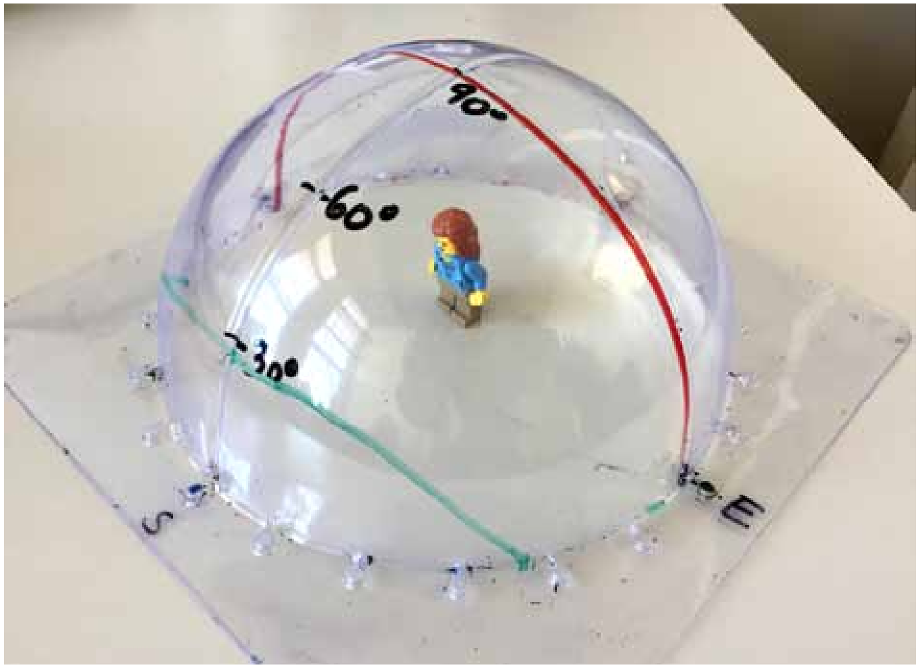

Figure 2: Physical modeling in the Seasons Lab. First students predict on a plastic hemisphere how the Sun might move in the Boston sky on December 21 (represented by the red line). Next, Students observe the Sun's true path across the sky in WWT, which they then transfer onto the same hemisphere (represented by the green line).

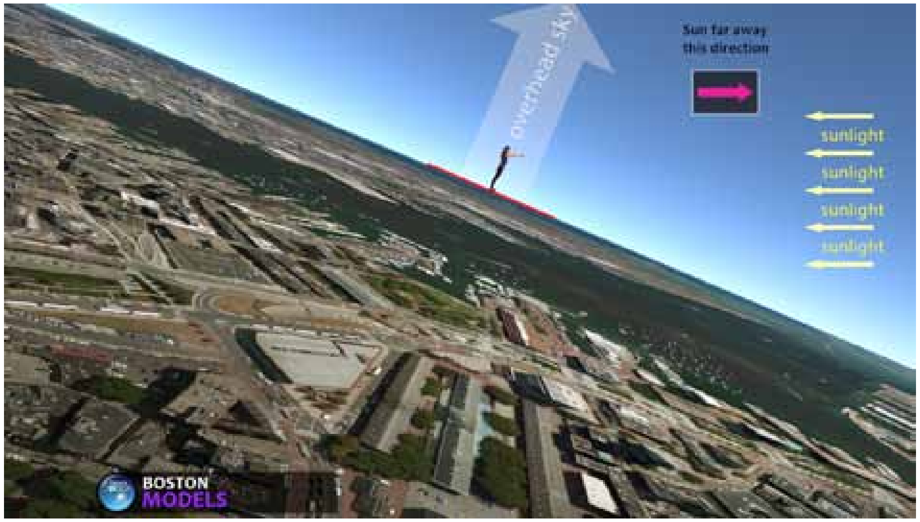

Figure 3: WWT image from the Seasons Lab. Students observe how sunlight hits the Earth at a certain time of day, relative to a person's location on the surface of the Earth.

Seasons

The most common misconception about seasons held by people, whether young or old, is that they result from a changing distance between Earth and the Sun. The ThinkSpace Seasons curriculum helps students build a strong, three-dimensional mental model of Earth and Sun, beyond the typical representations of a tilted Earth orbiting the Sun.

The Seasons Lab uses a blend of WWT visualizations and hands-on activities to emphasize connections between Earth- and space-based perspectives. For example, we ask students to predict the path of "today's" Sun, on a plastic hemisphere that represents the overhead sky (Earth-based perspective). Regardless of the date, close to 100% of the students initially predict that the Sun rises due East, travels straight overhead at midday, and sets due West. Next, they watch the true Sun path in WWT for whichever solstice or equinox is closest to the date of the activity. Students are surprised and intrigued to observe how different the actual path is from what they expected to see. Returning to their hemispheres, students mark the true locations of sunrise, midday Sun, and sunset, and connect those three points with a line to represent how the Sun actually appears to move in the sky (fig. 2).

This exercise gives students a concrete opportunity to correct their misconceptions, and to realize how much the Sun's path in the sky varies throughout the year. Without this fundamental understanding, students lack the requisite basis to understand why a tilted axis could cause Earth's seasons. From there, students investigate how sun angles affect the intensity of sunlight on the ground (space-based vs. Earth-based perspective). They then explore in WWT how to determine the angle of the sunlight, depending on your location on Earth and what time of year it is (fig. 3).

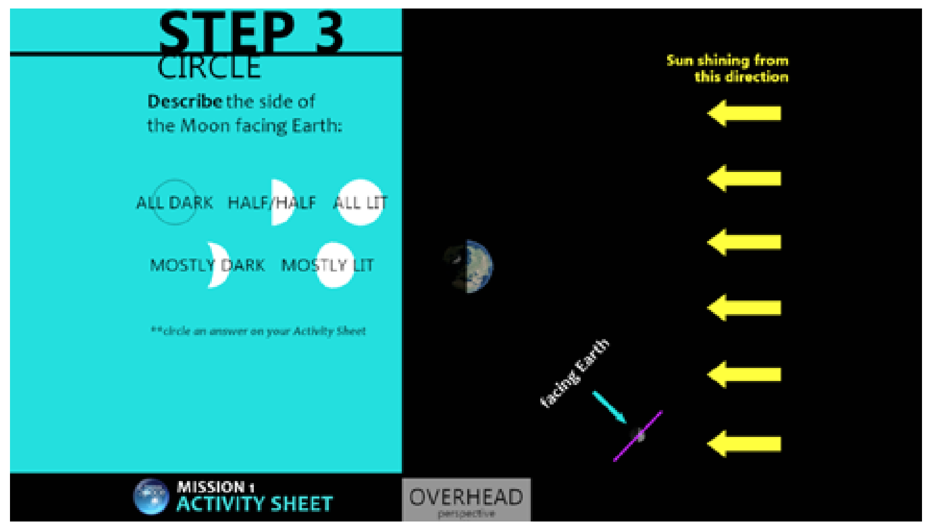

Figure 4: WWT image from the Moon Phases Lab. Students follow a four-step process to predict the Moon's phase from an Earth-based perspective, given the overhead location of the Moon in its orbit around Earth.

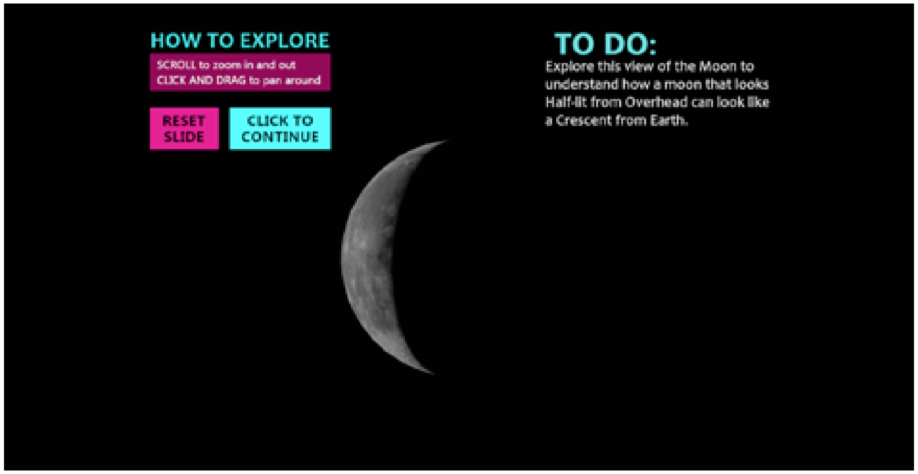

Figure 5: WWT Image from the Moon Phases Lab. Students can maneuver the perspective to investigate how a Moon that is always half-lit by sunlight can appear to have different phases from an Earth-based perspective.

Moon Phases & Eclipses

Like the Seasons Lab, the Moon Phases & Eclipses Lab engages students with a combination of physical and virtual models, and emphasizes the connection between space- and Earth-based perspectives in WWT. Given an overhead view of the Moon in a particular location in its orbit around Earth, students practice a 4-step method to determine what moon phase a viewer on Earth would see. A narrated sequence in WWT guides them through these steps (fig. 4). After practicing these predictions with both physical and virtual models, students can manipulate the Moon first-hand in WWT to see how a half-lit Moon from above can appear as a Crescent Moon to a viewer on Earth (fig. 5).

Because almost all static images of Earth and Moon together aren't depicted to scale, most students imagine Earth and the Moon much

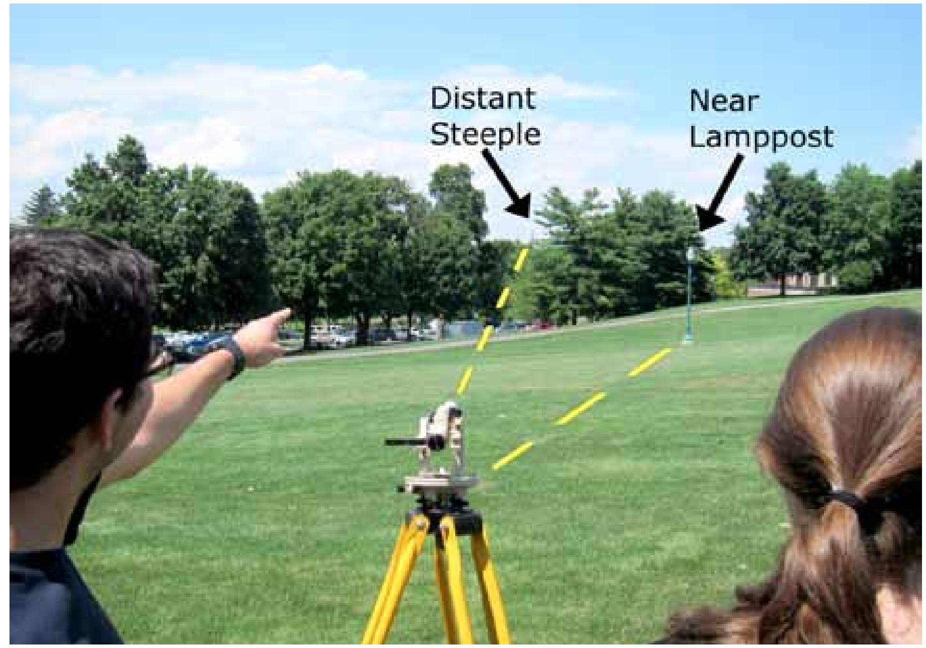

Figure 6: Real-world activity from the Parallax Lab. Students use the angular separation between a church steeple and a lamppost to measure terrestrial distances, in order to better understand the practice of making stellar parallax measurements.

closer together than they really are. This leads to two common misconceptions: that phases are caused by Earth's shadow falling on the Moon; or that lunar eclipses happen every month. WWT and physical modeling help students visually recognize that at the correctly-scaled orbital distance, the 5° tilt of the Moon's orbit is enough to avoid lunar eclipses during most months.

Bucknell

Prof. Ned Ladd of Bucknell University has incorporated WWT-based labs into his introductory astronomy course to help students visualize complex topics that are challenging to understand through the static diagrams of textbooks. Two of his labs are described here.

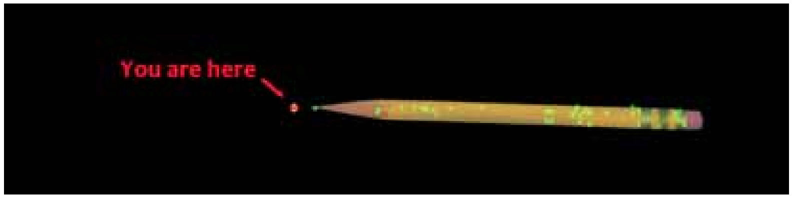

Figure 7: WWT Image from the Hubble Law Lab. Students can see from a distant perspective how the galaxies they have studied from the Sloan Digital Sky Survey occupy a line-of-sight pencil-like beam, extending out from the Earth.

THE PARALLAX LAB

Parallax, as applied to measurements of astronomical distance, is an abstract concept that can be difficult to intuit, because the positional shifts of stars (as seen from opposite sides of the Sun) are barely perceptible. In WWT, we can extend the baseline viewing locations beyond the real-world limit of the breadth of Earth's orbit. Using the Big Dipper as an example, we imagine how a star in the constellation would be positioned relative to a background star, when viewed from a position several light years away from Earth. From this new location, relative to our viewpoint from Earth, the Big Dipper stars shift by a noticeable amount, which students can measure directly from the screen. Students are able to use these measurements with their knowledge of parallax concepts to determine the relative distances to the stars in the Big Dipper.

Students then examine another concrete effect of parallax, on a local scale. They lay out a 2-meter radius circle to represent Earth's orbit around the Sun. Then they use a small telescope to measure the apparent angular separation between a nearby object (e.g., a nearby lamppost) and a distant object (e.g., a church steeple) (fig. 6), from various positions around their circular orbit. Students use their measurements to calculate the distance to the nearby object, which reinforces their understanding of how parallax is used to measure stellar distances.

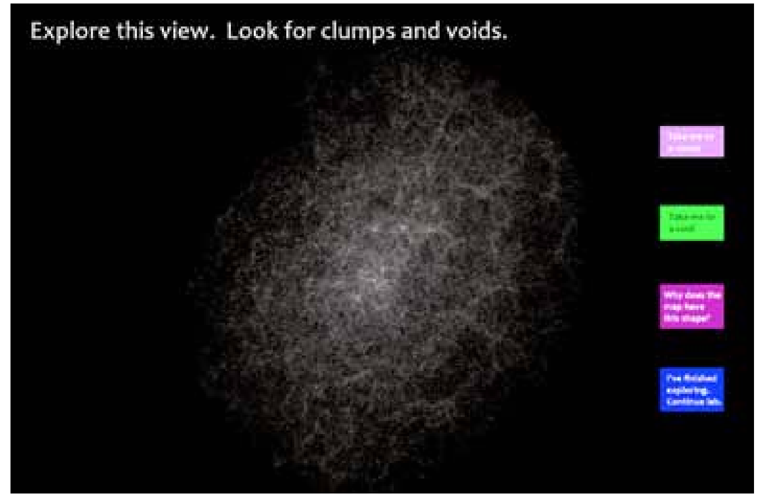

Figure 8: WWT Image from the Hubble Law Lab. Students can examine the breadth of galaxies in the known universe, as captured by the Sloan Digital Sky Survey and easily explorable in the WorldWide Telescope environment.

In the Hubble Law Lab students use WWT to measure the distances to galaxies in the real universe. Each lab group analyzes spectra for 3-4 galaxies from WWT's Sloan Digital Sky Survey (SDSS) catalogue to measure redshifts[1], and then estimate a distance to each galaxy using the Hubble Law relationship. Students then visualize these datasets within WWT, examining how the galaxies they have studied, when mapped in 3D, are clustered along the line of sight like a pencil beam (fig. 7). They can then explore in WWT more complete 3D maps from SDSS of the large-scale structure in the universe (fig. 8).

Life in the Universe

In the Life in the Universe (LITU) lab, students explore multiple aspects of the search for alien life. The lab gives an overview of our

1 Redshift is the shift of spectral lines from astronomical objects toward longer wavelengths. As an object moves away from Earth, light shifts toward the red end of the spectrum (not necessarily within the range of visible light). Redshift is a useful measurement when estimating the distances to galaxies, using Hubble's Law.

Figure 9: WWT image from the Life in the Universe Lab. Students can observe the distribution of known exoplanets in our galaxy depicted as purple dots mapped to the Milky Way.

place in the solar system, our place in the Milky Way galaxy, and then an exploration of galaxies beyond our own. Students then learn how scientists use the transit method[2] to search for extrasolar planets, and where extrasolar planets have already been discovered (fig. 9). Next, students learn about the conditions that make a planet habitable. Finally, students consider relative distances in our own galaxy, and calculate how long it would take to communicate with or travel to alien life.

As they build knowledge on the topic, students also consider what it would mean for our society should life be found beyond Earth.

2 *The transit method is one of the key methods used for detecting planets around other stars. Astronomers look for periodic dips in brightness from distant stars, at a consistent interval of dimming. This predictable dimming pattern indicates that an exoplanet is blocking a portion of the star's light as the planet follows its orbit around the star.*

Facing broad and potentially complex issues, students gradually find the confident and inquisitive voice they need to generate unique questions of personal interest that will guide their group project. LITU aims to engage students in the complete process of scientific inquiry: understanding context, learning to ask open-ended questions, and then investigating how one might attempt to answer such questions.

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WWT is a free resource available to any institution or member of the public. WWT exists as both a web-based tool, as well as a Windows-only application that can be downloaded to your computer. Because the application has the flexibility to be used either entirely online or on a local computer, WWT has the potential to reach an ever broadening and diverse audience, including populations that are traditionally underserved in STEM education. Today, the user base of WWT is in the tens of millions, and all versions of the software are freely accessed at worldwidetelesope.org.

American Astronomical Society WorldWide Telescope AAS

About the Author

Harry Houghton came to astronomy education by way of educational publishing and education research. While earning his Masters at the Harvard Graduate School of Education in 2015, Harry joined the WorldWide Telescope Ambassadors team, and has been with them since. The focus of his masters was the effective use of technology in educational programming, which has motivated how he approaches the design and inclusion of WorldWide Telescope in classroom learning. As beautiful and immersive as WWT is, the success of any curriculum is measured by how well the students connect with new and potentially foreign subject matter. Harry also works for the Science Education Department at the Center for Astrophysics | Harvard & Smithsonian, where he creates media to support a number of out-of-school projects that engage and inspire students of all backgrounds with the real science of Astronomy.

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