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WorldWide Telescope & Google Sky New Technologies to Engage Students & the Public

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Abstract. New, visually rich, astronomical software environments coupled with large web-accessible data sets hold the promise of new and exciting ways to teach, collaborate, and explore the universe. These freeware tools provide contextual views of astronomical objects, real time access to multi-wavelength sky surveys, and, most importantly, the ability to incorporate new data and to produce user created content. This interactive panel examined the capabilities of Google Sky and WorldWide Telescope, and explored case studies of how these tools have been used to create compelling and participatory educational experiences in both formal (i.e., K-12 and undergraduate non-science majors classrooms), and informal (e.g., museum) settings. The overall goal of this session was to stimulate a discussion about future uses of these technologies. Substantial time was allotted for participants to create conceptual designs of learning experiences for use at their home institutions, with feedback provided by the panel members. Activities included technical discussions (e.g., mechanisms for incorporating new data & dissemination tools), exercises in narrative preparation, and a brainstorming session to identify potential future uses of these technologies.

1. Introduction to WorldWide Telescope & Google Sky

WorldWide Telescope (WWT) and Google Sky are new and evolving web-based tools. They are essentially desktop planetaria or virtual telescopes that are connected to vast astronomical databases. Both applications are freeware, and both allow users explore the night sky and deeper layers of information in a very intuitive manner. They offer holistic experiences by providing the ability to zoom, pan, and dig deeper into underlying data. They provide a context for an object's size and location with views that seamlessly shift from the entire sky to individual astronomical objects (e.g., one can query an object and then be smoothly flown to it). Both applications exploit the growing number of large, web accessible, astronomical data sets (e.g., SDSS). Other common features include the ability to view observations in multiple wavelengths or in historic images (e.g., constellations) and to blend and fade from one view to another. Both also encourage user added content. This combination of immersive visual experience, real data, and user added content make these software packages powerful tools for presentations, formal and informal education and for self-directed learning.

1.1. **WorldWide Telescope Tours -** http://www.worldwidetelescope.org

WorldWide Telescope (WWT) provides a multi-media publishing environment via its Tours feature (Wong 2008). Tours are guided experiences exploring WWT and the data within and queried by WWT. They are literally guided tours of the universe. Tours can include sound tracks and narration, as well as user added images and data (e.g., photos, panoramas, graphs, and simple animations). One can create and publish tours locally or broadly via the WWT site. Tours open a world of possibilities for creating narratives for all types of audiences. They also enable self-directed learning as they can be paused at any point as a user chooses to explore on their own.

1.2. **Google Sky Features -** http://www.google.com/sky/

Google Sky has the ability to add interactive features by programming in a mark-up language called KML. For example, an undergraduate galaxy cluster lab utilizes KML to dynamically generate a color magnitude diagram using the SDSS galaxies visible in a given view, as one moves around the sky. It is also possible to embed Google Sky in any webpage - this is analogous to creating a Google Map mash-up or embedding a map into a webpage.

1.3. Tiling the Sky

Modern astronomical imaging surveys are producing tremendous quantities of data, and the exponential expansion of data in the recent past promises to continue with upcoming surveys like the Large Synoptic Survey Telescope. Unfortunately our ability to transmit information over the network is not increasing at such a rapid rate. Google Sky and WorldWide Telescope have tackled this problem by creating viewers for tiled multi-resolution images. This approach consists of a tiled pyramid of an image at multiple resolutions, each progressive resolution is composed of increasingly more tiles and is stored as a different layer. Delivering these tiles as web services means only the data/tile that is being displayed at the resolution requested needs to be transmitted over the network. This dramatically reduces bandwidth requirements. Furthermore, this paradigm is scalable as future bandwidth needs only need to keep pace with increasing display sizes, rather than the unmanageable increase in data flow.

One complication remains - mapping the spherical sky onto a flat map. Ideally this is done in a way that introduces minimal distortion in the images and does not produce pinching at the poles. To do this the WWT team has produced a projection scheme called TOAST[2], which is based on the hierarchal triangular mesh scheme developed to catalog objects in the Sloan Digitals Sky Survey (Kunszt et al. 2001). This triangular mesh equally weights different areas of the sky, unlike common rectangular projections. Google Sky currently has adapted the projection scheme used for Google Earth/Maps. This more traditional mapping introduces visual artifacts at the celestial poles.

2. Inquiry-Based Education Using WorldWide Telescope in the K-12 Classroom

WorldWide Telescope (WWT) provides a unique opportunity to do hands-on inquiry-based astronomy education with K-12 students. Active exploration, where children learn to answer their own questions by doing investigations, offers deeper comprehension and generates stronger enthusiasm in students. This is the essence of inquiry-based teaching. This section describes work done by Science Specialist Dettloff using WWT for inquiry-based astronomy with upper elementary level students at the Nueva School, an independent school for gifted children in Hillsborough, California,

The lure and mystery of outer space draws students into astronomy activities and discussions. However, it is difficult to provide students with something astrophysical to put their hands on and manipulate. This creates a dilemma for inquiry-based astronomy teaching. Real inquiry seemingly would require that students fly through the universe to compare the shapes of galaxies, or to measure the magnitudes of the stars in an open cluster, but that isn't possible. WWT offers the ability to actively investigate the night sky.

At the Nueva School, Dettloff and Estes created a science program based on active investigation in which concepts are developed after activities, and naturally fall out of the experiments and observations. They developed this process into the *Cycle of Inquiry Lesson Model* (Estes 2007). In this model, students are guided further and further into independent investigation, teaching them to design their own experiments. Cycles begin with an intriguing hook to draw students into the investigation. Awareness of all the factors that might affect the outcome of the experiment is an important part of this process. Students carefully consider what variable they are going to change, what to hold fixed, and what to measure or observe. The questions that naturally arise from the results of these investigations become the seeds of new experiments. Through several "cycles of inquiry", the children become increasingly independent in their experiment design. Moving from direct instruction, where the teacher provides the content, to full inquiry can deliver deeper levels of competence and insight in science. (Estes and Dettloff 2008).

As a planetarium instructor for many years at the Lawrence Hall of Science, Dettloff was often struck by the unfair fact that she had the best seat in the house, because she got to manipulate the controls. She often spent time after her shows playing with the projector controls (e.g., changing latitude or moving the sun and moon

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[2] http://www.worldwidetelescope.org/docs/WorldWideTelescopeProjectionReference.html#WorldWideTelescopeProjectionReference

along the ecliptic) to look for interesting patterns and connections. She was deeply aware that her planetarium visitors didn't have this opportunity, although her planetarium shows were interactive, allowing the participants to suggest changes (e.g., in the latitude or time) and then make measurements and observations. Even this level of inquiry provided the participants with a deeper level of comprehension than a program where information was delivered to them. Dettloff's own experimentation with the planetarium controls was in effect active inquiry and experiment design, deciding what variables to change and what to keep fixed. This experience fueled interest in WWT.

WWT offers a mechanism to incorporate both the self-taught inquiry of piloting a planetarium and the inquiry-based teaching of the *Cycle of Inquiry*. Students are first shown an intriguing astronomical hook, and then challenged to come up with a question that can be answered using WWT as a tool. The students must determine what variable to change and what they will measure or observe.

WWT's "View" menu facilitates this experimentation. Control bars for time and location allow one to explore, change variables, and quickly see the effects. This can be used to watch objects during specific times of the night, lunar cycle, or year. For example, one can rapidly zoom in on the moon and observe its changing shape as weeks pass, creating a very dynamic experience. The same technique can be used to watch how Mars or Jupiter move across a background of distant constellations as months pass.

Table 1. An Inquiry-based Student Challenge

1)	Identify the situation you want to explore.
2)	Identify the question you want to answer with your research.
3)	Identify the variable you want to change.
4)	What will you measure or observe?
5)	What happens in your investigation?
6)	What further questions develop out of your results?

In a simple example, a student might want to know where in the sky the Big Dipper appears in different parts of the world. The Experimental Question might be: *How will the Big Dipper look different if we jump from Hawaii to Alaska at midnight on Christmas Eve?* The variable is the latitude, with the time of the night and the year being held constant. The observables are the height and angle of Big Dipper in the sky. From this experiment, a new question might emerge: *How did the Big Dipper look at midnight on Christmas Eve a thousand years ago in Hawaii?*, changing the variable from "latitude" to "year". Such exercises offer a wonderful opportunity to help children gain awareness of all the factors that might affect the outcome of an experiment. Part of the student's task is to clarify what they will keep fixed, what they will change, and what they will observe.

WWT goes beyond constellations and offers genuine observational data that can be used for student inquiry. For example, the cross-fade slider, which allows the user to slowly fade between images from different data sets, provides another opportunity for change and comparison. One could explore the Ring Nebula with Hubble Space Telescope and then look at it in a different wavelength or in the all-sky survey. The Experiment Question might be: *How do objects in space look different through the*

Hubble Space telescope? Students would identify the variable as the data collection source and the direction and zoom as factors to keep fixed.

Because there are so many opportunities to change variables in WWT, the possibilities for inquiries are vast. As the students and instructors at the Nueva School played with it, they found more and more ways for students to interact independently with it, following their passion and curiosity.

3. Google Sky in the Undergraduate Non-Science Major Classroom

Faculty members at the University of Chicago were motivated to work with Google Sky and WorldWide Telescope (WWT) by a desire to improve the non-science major undergraduate curriculum. They sought to make labs more engaging, participatory, and reflective of current astronomical research practices. WWT and Google Sky were natural choices for this, as they provide mechanisms to incorporate current research and data into active, visually stimulating, educational experiences. Additionally, they offer students the flexibility to work outside the lab/classroom. Thus far Google Sky has been incorporated into three non-science major laboratories, which have been used in six different classes. An informal survey of students using these labs, found that the faculty experiment was successful in bringing real research into the classroom, but it also indicated that there is room for improvement.

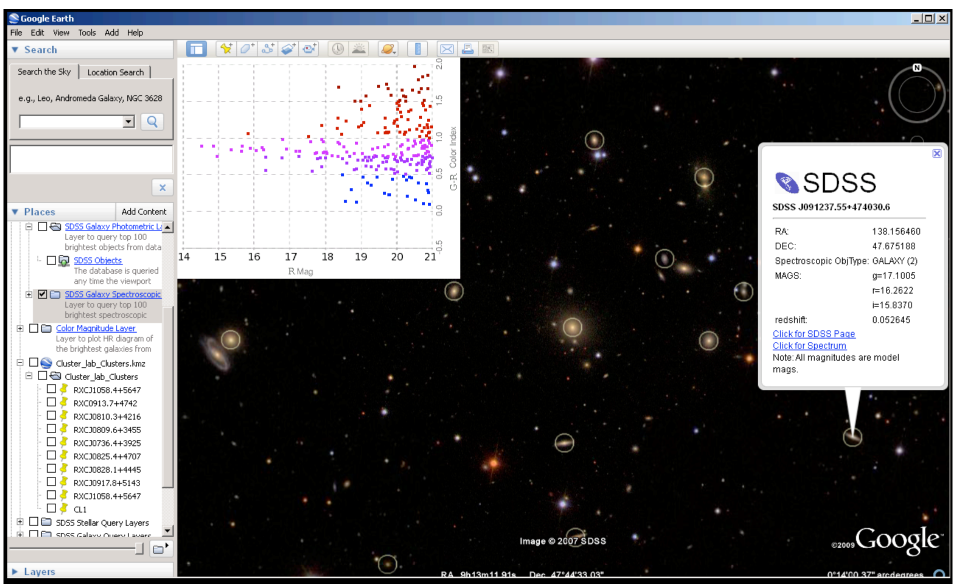

Figure 1. An example of an undergraduate laboratory that utilizes KML programming in Google Sky. The automatically generated color magnitude diagram is used to identify galaxy clusters.

The Google Sky labs are part of a history of exploring visual technology to bring current research to both formal and informal educational settings in Chicago.

Relevant recent manifestations of this are a pair of workshops hosted by the Kavli Institute for Cosmological Physics (KICP): *The Visualization of Astrophysical Data: Bringing together Science, Art and Education* in 2005[4] and *Viewing the Universe via the World Wide Web* in 2008[5]; and the *Astronomy Conversations* program at Adler discussed later in this paper. The 2008 workshop was specifically designed to examine the capabilities of WWT and Google Sky. It brought together the developers of the software, astronomers, formal and informal educators and educational researchers. The undergraduate laboratories discussed in this paper were a direct consequence of this workshop.

Andrey Kravtsov and graduate student Sam Lietner, with the help of institutional support[6], developed three Google Sky laboratories. These exercises offer students hands-on visual experiences with key astronomical concepts: from the evolution of stars, to the expansion of and large-scale structure of the universe. They were field tested in courses during the winter and spring quarters of 2009**.** Labs developed thus far are:

Galaxy Spectra and the Hubble Law: Students explore the connection between galaxy morphology and galaxy spectra. They then use BCG (brightest cluster galaxy) brightness and redshifts derived from spectra to create a Hubble diagram.

HR Diagram: Students explain the HR diagram of stars in globular clusters, open clusters (SDSS) and the local disk (Hipparcos), using a KML plugin that plots a color-magnitude diagram of stars in the Google Sky field of view.

Exploring Clusters: Students use a similar dynamic color-magnitude diagram plugin as in the *HR Diagram* lab to find clusters using their red sequence (figure 1). Students also apply the virial theorem to clusters to demonstrate missing mass.

Two more labs are in the development phase: *QSOs and Stars, and Studying Isotropy with magnitude Limits.* [8]

The Google Sky labs were incorporated into the curricula of six classes that reached 247 students. This includes two courses at the UC center in Paris, where the laboratory equipment is limited and web-based labs provide an excellent option. The labs were used in non-science majors astronomy courses, designed for students in the humanities and social sciences for their general education requirement in the physical sciences (i.e., distribution requirements). The specific courses were: Evolution of the Universe, Natural Sciences (NTSC) 10200, and the somewhat more rigorous sequence Stellar Astronomy and Astrophysics, Physical Sciences (PHSC) 11900, and The Origin of the Universe and How We Know, PHSC 11200.

Survey Summary

The survey found that many of the intended outcomes of incorporating this new technology into the classroom were successful. Specifically the students reported that they had a better appreciation for real astrophysical research and the universe itself, that it had improved learning, and over a quarter of the students were using

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[4] http://kicp-workshops.uchicago.edu/visualization2005/
[5] http://kicp-workshops.uchicago.edu/universe2008/
[6] A grant from the Provost of the University of Chicago's Advanced Technological Innovation (ATI) program funded six new student laboratory computers and 50% support of a graduate student.
[8] Beta-versions of these laboratories and the associated KML files can be found at: http://astro.uchicago.edu/~sleitner/outreach/

Google Sky outside of the classroom. These exercises however still suffer from shortfalls typical of student labs (e.g., quality of written instructions). Specific areas for improvement related to the new technology included the desire for more hands-on experiences and fewer repetitive tasks. Student comments touched on both the power of visual technology that accesses current research data, and the difficulty in trying to model genuine inquiry while creating something robust enough for the classroom.

3.1. Survey Methodology

Students enrolled in the 2009 spring quarter NSTC 102 (92), and PHSC 120 (46), were invited to participate in the survey by their teaching assistants via email after the term had ended. The surveys were voluntary, informal, and anonymous (i.e., not rigorous). They were web based and short, consisting of nine questions. The questions probed the general quality of the laboratories offered as well as specific indicators regarding the Google Sky labs. Although the two courses offered different labs, the questions were designed to be identical except for those rating specific labs. Consequently the data has been combined for brevity. The overall response rate was **39%**, with 34 respondents (37%) for NSTC 102 and 20 respondents (43%) for PHSC 120.

3.2. Survey Results

A pair of open-ended questions probed what the students did and did not appreciate about the labs that involved Google Sky. Many of the responses were similar and naturally fell into a few general categories. LIKES – easy, cool, pretty, interactive, and real view of the universe. DISLIKES – boring, tedious, lack of learning, no hands on, long, poor write-ups &/or technology. Representative student responses:

LIKES

- *It allowed us to examine the universe holistically and apply the information we had learned in class to navigating the structures of the universe.*
- *Easy way of getting at more complex and advanced empirical research*
- *They were cool in that we could see the actual objects and search and identify them. The visual effect made it much easier to absorb the information.*
- *I liked that they were designed to be similar to how actual astrophysicists research.*
- *the results we got reflected what we were learning about and we got to see where the info for the diagrams came from*
- *It was interesting to see the universe in a different light. I was given an opportunity through this lab to see things I would never see outside of it.*

DISLIKES

- *The Google Sky labs were mostly computer tasks, and I like the more hands on experiment type labs that include an actual apparatus.*
- *I felt that they were excessively tedious.*
- *If you have to repeat 10 + times the same thing (e.g. taking spectra) then it gets very boring.*
- *they took a lot of time, but the time spent was on worthless tasks like counting stars instead of focusing on the actual concepts*
- *I felt I missed the entire purpose of the labs when we merely counted white dots on the screen*

Three yes/no questions probed the impact of Google Sky labs in and beyond the classroom. These indicators were by and large positive. Over a quarter of the students use Google Sky outside of class time, more then half felt that the labs had helped them to learn the course material better or to learn a useful skill, and nearly three-quarters of the students indicated that the labs increased their understanding of modern astrophysics research.

Table 2. Yes/No Indicators

Did you use Google Sky outside of classroom/lab?	29% YES
Do you feel the Google Sky labs helped you to learn the course material better or taught you any useful skills?	59% YES
Did the Google Sky labs increase your understanding of what modern astrophysics research is like?	73% YES

Figure 2. The WWT driven multi-wavelength exhibit at the Adler Planetarium and Astronomy Museum.

4. WorldWide Telescope in Museums

The Adler Planetarium and Astronomy Museum utilized WorldWide Telescope (WWT) in a new exhibit on the history of the telescope, “Telescopes: Through the Looking Glass”. While the exhibit houses some of the oldest telescopes in existence, the WWT based exhibit pieces are used to provide digital access to images from modern observatories. There are two WWT components in the modern section of the gallery. The first, a multi-wavelength sky viewer, makes use of a custom WWT build to synchronously drive four large displays, each showing the same region of the sky in a different wavelength (X-ray, UV, Optical, or Infrared). Each view also contains a low resolution all sky survey with overlaid higher resolution pointed observations from Chandra, Hubble and Spitzer (figure 2). The second gallery piece represents our current view of the Universe. It makes use of the "Universe" mode of WWT, allowing visitors to fly from the solar system, through the Milky Way Galaxy and out through nearly 800,000 galaxies in the Sloan Digital Sky Survey.

WWT is also utilized for interactive presentations where research scientists use multimedia tools to discuss their science with museum visitors. The *Astronomy Conversations* program strives to combine real data, real scientists, visually appealing resources and the public to create a dialog about current research. WWT is frequently used in this setting to give context to the images being discussed. These technologies have tremendous potential in the museum environment, which we are only beginning to tap.

5. Workshop Participant Activities

Participants developed a list of project ideas during the workshop. The initial list of ideas included:
Learn the constellations
Time-lapse movie of how the sky changes
See what the sky looks like from different places on the earth
Zoom in and zoom out
Scrolling wavelengths - multi-wavelength sky
Examining huge structures like the Milky Way and other galaxies. Powers 10
Tour of ultra-high energy cosmic ray sources
W-map data: to be able to see it as the blanket sky.
Adjust the contrast of false color images
Tour of stars in different parts of the cycle (evolution of stars)
Look for asteroids by looking at different colors in the Sloan image
Winter sky

For the concluding activity of the workshop, the group selected two projects and divided into to teams for a rapid, hands-on, development session. In 20 minutes, the teams created the solid beginnings of two WWT tours: *A Zoom Out From The Earth to the Large Scale Structure Of The Universe* and *A Multi-Wavelength Examination Of The Orion Nebula*. Each team presented their test project concept and progress to the group as a whole. This facilitated exercise demonstrated both the versatility of WWT and the relative low threshold for creating something with these new technologies.

6. Conclusions

WorldWide Telescope and Google Sky offer innovative ways to teach and learn. This paper explored just a few of the current applications of these technologies. Given the combination of immersive visual experiences, real data, and user added content that these software packages offer, and the responsiveness of the software development teams to the user communities, we can expect many new and exciting future uses of these technologies both in and beyond the classroom.

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