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Visualizing Moon Phases with WorldWide Telescope

Patricia Udomprasert, Alyssa Goodman, Susan Sunbury, Zhihui Helen Zhang, Philip Sadler, Mary Dussault, Sarah Block, Erin Lotridge, Jonathan Jackson, and Ana-Maria Constantin

Harvard–Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138, USA

Abstract. We report preliminary results from an NSF-funded project to build, test, and research the impact of a WorldWide Telescope Visualization Lab (WWT Vizlab), meant to offer learners a deeper physical understanding of the causes of the Moon's phases. The Moon Phases VizLab is designed to promote accurate visualization of the complex, three dimensional Earth–Sun–Moon relationships required to understand the Moon's phases, while also providing opportunities for middle school students to practice critical science skills, like using models, making predictions and observations, and linking them in evidence-based explanations. In the VizLab, students use both computer-based models and lamp + ball physical models.

We present findings from the first two phases of the study—one in which we compared learning gains from the WWT VizLab with a traditional two dimensional Moon phases simulator, and another in which we experimented with different ways of blending physical and virtual models in the classroom.

1. Introduction

Bransford et al. (2000) advocate for development of innovative curricular materials that address key concepts of a particular discipline, address students' prior ideas, and provide strategies and tools teachers can use to help students bridge naïve and mature understandings within the discipline. America's Lab Report points out that students receive few realistic lab experiences, and most are "cookbook"-type labs in which students reproduce a rote series of steps that do not teach them about scientific processes or give them new insights into the content they are studying (Singer et al. 2006). WorldWide Telescope Visualizations Labs (WWT VizLabs) have been planned in response to this need for research-based innovative curricular material that is feasible for teachers to integrate into existing curriculum.

We report here on the development and testing of the first planned WWT VizLab, designed to teach students about the cause of eclipses and the Moon's phases. The lab was implemented in the WorldWide Telescope (WWT) computer program, a beautiful, powerful, freely available data visualization environment developed by Microsoft Research in collaboration with professional astronomers. Several pilot studies have shown that WWT not only offers excitement and engagement, but it also significantly improves student understanding of astrophysical concepts (Udomprasert et al. 2012).

2. Design, Assessment, and Implementation of the Moon Phases VizLab

Uttal & Doherty (2008) caution that novices often have trouble connecting components in a visualization to the individual parts that they are meant to represent. Because these connections seem obvious to experts, teachers fail to point out these crucial links to students. With this in mind, we sought to include both a physical model (e.g., Styrofoam balls and a lamp) and a computer visualization in designing the Moon Phases VizLab. We offered multiple opportunities for students to consider the connections between the physical model, the computer model, and the actual Earth, Sun, and Moon system.

To assess student learning, we created and used identical pre- and post-tests that include multiple choice content questions about the Moon's phases and open response questions that probe understanding of the cause of the Moon's phases. The multiple choice questions were selected from the Astronomy and Space Science Concept Inventory (ASSCI, Sadler et al. 2009), which is based on the K–12 science standards (American Association for the Advancement of Science 1993; National Research Council 1996) that involve Astronomy and Space Science. The ASSCI questions are distractor-driven multiple choice questions that allow an evaluator to determine whether students hold a scientifically accepted understanding of a concept or whether they still hold non-normative ideas after an intervention. Offering a view distinct from the multiple-choice approach, open-response questions were scored using a Knowledge Integration (KI, Linn 2000) rubric designed to measure how well students integrate scientifically normative ideas into their reasoning.[1]

3. Student Learning Outcomes

Phase 1, Massachusetts School A, Fall 2012. We tested the first iteration of the Moon Phases VizLab with two sixth-grade teachers at a public middle school in an Eastern Massachusetts town (School A), who each teach about 80 students in four classes. In order to compare WWT's rich 3–D visualizations with a traditional 2–D simulator, we created two different, but parallel, versions of the intervention. Both teachers divided their students into groups (two treatment and two control classes per teacher) with comparable student ability. The treatment group used WWT as the computer simulation, and the control group used a 2–D simulator recommended by the students' textbook, and already in use by one of the teachers. We refer to the 2–D visualization as the "textbook simulator" or "TS"[2] and the 3–D visualization as "WWT."

Students in both Phase 1 groups (WWT and TS) showed strong learning gains (see Fig. 1), but the WWT group outperformed the TS group. We attribute this to the added richness (interactivity, three dimensional views) offered by WWT in contrast to the TS. A t-test showed the gain difference between the two groups to be statistically significant, with a probability of the gains for each group being drawn from the same distribution being 3%.

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[1]The latest version of the WWT Moon Phases VizLab can be downloaded from `https://wwtambassadors.org/wwt/WWT-MoonPhasesVizLab`.

[2]The simulator can be found at `http://www.astro.wisc.edu/~dolan/java/MoonPhase.html`, which is used in Activity 81, pg. F-48, of *Issues and Earth Science* (University of California, Berkeley, 2006).

		Averages (and standard devations) Max Possible Score=7			Effect Size
		Pre	Post	Gain	
School A	WWT	2.7 (1.2)	5.1 (1.3)	2.5 (1.3)	2.0
	TS	2.6 (1.2)	4.3 (1.4)	1.7 (1.6)	1.5
School B	WWT	2.7 (1.5)	4.4 (1.7)	1.7 (1.5)	1.1

Figure 1. A comparison of average pre/post-test scores, gains, and effect sizes for students in School A, who used WWT vs. the Textbook Simulator (TS), and for students in School B, who all used WWT.

Phase 2, Massachusetts School B, Spring 2013. We tested a second iteration of the VizLab with one eighth-grade teacher and 70 students at a second public middle school in Eastern Massachusetts (School B). For this phase, all students used WWT as the virtual model. The third row of Figure 1 shows learning gains and effect sizes for all students in School B.

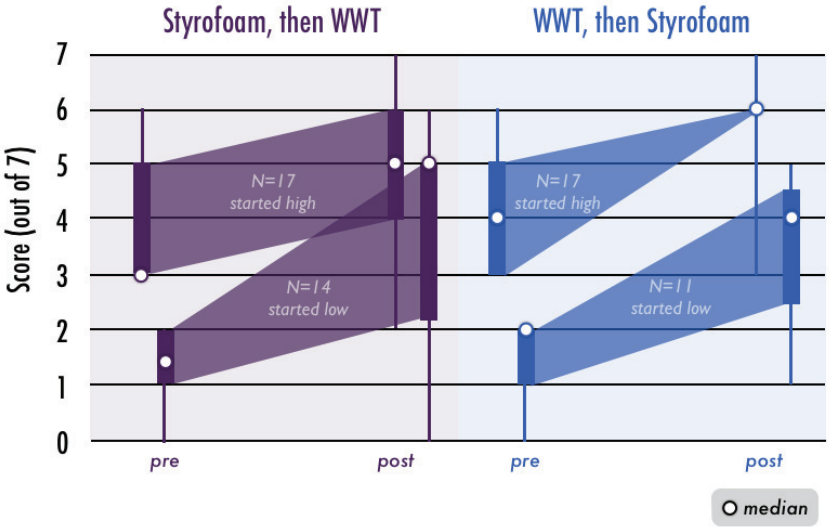

Figure 2. A box-and-whisker plot comparing learning gains of School B students who used the Styrofoam balls first, then WWT, vs. students who used WWT first, then the Styrofoam balls. Plotted are the full range (thin lines), inner two quartiles (rectangular boxes), and medians of pre/post-test score distributions.

During Phase 2, we tested two different activity orders: WWT, then Styrofoam; vs. Styrofoam, then WWT. Figure 2 shows the change in pre/post-test scores for the two different sequencing of activities. We found that students with low prior knowledge benefited from using the Styrofoam ball model first, while students with high prior

knowledge benefited from using WWT first. We hypothesize that students with low prior knowledge had trouble interpreting the complex 3–D computer visualization (as cautioned by Uttal and O'Doherty 2008) because they were not familiar enough with the mechanics of the Earth–Sun–Moon system to understand the computer model. We are unsure why the students with high prior knowledge benefitted from seeing the 3–D visualization first, but we speculate that their high level of engagement with the program could have been a factor.

4. Student Interest Outcomes

Phase 1, School A Students who worked with WWT were more engaged and more interested in continuing to use the visualization than those who used the "traditional" simulator. After the post-test was completed, students were given the option to continue exploring "a computer model of our solar system," or to quietly read a book. At that point 95% of the students in the WWT classes chose to continue their explorations in WWT, even after the post-test was given and the unit was complete. The TS students had not yet seen WWT, and about 50% of those students at first opted to read a book. The TS students who did choose to explore the computer model were taught how to use WWT for the first time. After observing their peers use WWT for a few minutes, 100% of the book-readers in the TS classes stopped reading and asked to try WWT.
Phase 2, School B Students reported their level of interest in astronomy on the pretest and post-test. On the pretest, 25% of students reported little or no interest in astronomy. On the post-test, after completing the three-day WWT Moon unit, 70% of those non-interested students reported a higher level of interest in astronomy.

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