

EDUCATIONAL EXPERIENCES FOR K-12 IN THE EARTH AND PLANETARY SCIENCES.

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Introduction: Career opportunities in science, technology, engineering, and math (STEM) are predicted to grow by 17% between 2008 and 2018 [1]. Yet, graduation of STEM college students is expected to fall short of need by 1 million over the next decade [2]. STEM Education and Public Outreach (E/PO) offers an avenue of engaging and exciting the community about STEM topics and careers. Engaging kindergarten through high school (K-12) students in STEM related outreach activities can be the catalyst for students to start, continue, and retain educational and career paths within STEM fields [3]. The work presented here is part of a 10 month project funded by the NASA Nevada Space Grant Consortium to develop a series of engaging, interactive, and educational informal activities targeted at K-12 participants and emphasizing STEM concepts. Our developed outreach activities are expected to become part of a "library" of informal experiences and related supplemental materials for ongoing outreach by the UNLV Department of Geoscience, eventually reaching beyond K-12 to include college undergraduate and graduate students (if interested, please contact Christopher Adcock adcockc2@unlv.nevada.edu).

E/PO Events: Our current project includes three developed E/PO K-12 events. Each event begins with a short presentation, followed by a 30-45 minute group activity, and concludes with a follow-up discussion. Outreach materials are made available for ongoing use by participants and teachers. In addition, the events conclude with an "experience reminder" (an inexpensive souvenir to remind the participant of the event) such as a 3D printed 1"x1" Olympus Mons. The three activities currently developed for this project focus on planetary exploration, planetary volcanism, and solar system scales.

Mission to Planet Alpha Event. The E/PO event applies gamification [4] (i.e. applying game mechanics to non-game contexts such as education) to introduce students to the complexities, tradeoffs, and risks involved with developing and performing unmanned space missions. The event also explores aspects of astrobiology and potential extraterrestrial life.

The event begins with a short presentation on exploring planets and moons, both in our solar system and beyond. The presentation includes instructions on how the game, *Mission to Planet Alpha*, is played. At the end of the presentation, participants break into groups and play a game. The game is table top simulation of an unmanned mission to a fictional

planet. The mission objective is to explore the fictional planet and search for signs of life. Each group is assigned a different fictional planet. The simulation includes resources, such as available launch vehicles and science equipment for the mission. There are also limitations, such as weight, energy, and monetary budgets. Participants assemble a spacecraft within the limitations and launch it. During the mission "events" occur that can help or hinder the mission. For example, a game event might include a collision with a micro-meteorite that eliminates an instrument on the probe.

Upon arrival at the planet, participants are presented with an image of their planet and some general facts (see example Figure 1). The mission then "deploys" the science package. Depending on what instruments were chosen, different facts specific to the planet are revealed. Because the participants have no foreknowledge of the planet, there is a possibility that the science package they chose is not well suited for the mission. The activity concludes with a discussion of what life forms might look like on other planets (based on discoveries during the game) and different mission choices that might have been made.

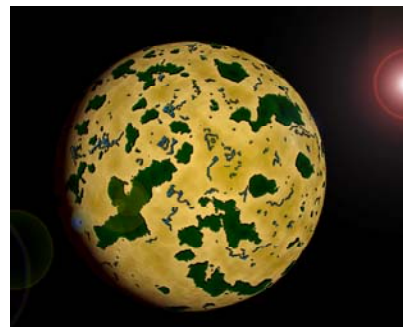


Figure 1. One of five fictional planets in the *Mission to Planet Alpha* game. This planet has a thin atmosphere, large briny lakes possessing a green substance, and a barren desert-like land surface.
Image: Chris Adcock 2014

Volcanoes in the Solar System Event. This event begins with a presentation on volcanoes, including a "tour" of volcanoes on other planets or moons (e.g. Enceladus, Io, Mars). The presentation utilizes data or visualizations obtained from the NASA Planetary Data System, Planetary Photojournal, and the Eyes on the Solar System product. After the presentation, samples of volcanic rocks are made available to participants as well as a 3D printed model of Olympus Mons (Figure 2). The event includes a demonstration of pumice floating in water and a model volcano demonstration with participant volunteers. The activities conclude with distributing a 12"x17" volcano poster to

participants as well as a larger class size version for the classroom (Figure 3).

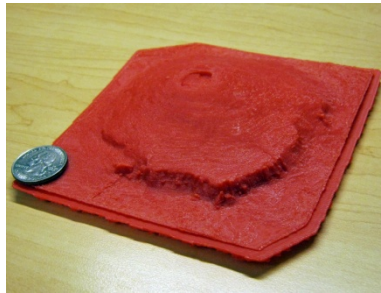


Figure 2. A 5"x5" 3d printed model of Olympus Mons on Mars. Model has 6x vertical exaggeration. Data for models is sourced from MOLA and HIRISE DEMs. Smaller models may be used as experience reminders for E/PO events.

Solar System Scales Event. Like the other events, mission data obtained from the NASA PDS, Planetary Photojournal, and visualizations from the Eyes on the Solar System product are used in a short presentation before a group activity. The activity in this event is an outdoor exercise using a scaled Sun and planets. Participant volunteers play the role of the Sun, planets, and major moons, and each hold a rod with a scaled representation of a planet, moon, or the Sun. The participants stand at distances apart which represent the scaled distance between objects. With the Sun being a 2.5 cm sphere, the distance to Neptune would be roughly 90 meters (Mercury would be represented

by the diameter of a section of fishing line). There is also a 1.25 cm Sun option (45 meter solar system). Following this exercise, a second exercise demonstrating the distance from our star to other nearby stars is conducted. The activity concludes with a handout for participants that includes a table of solar system distances based on different size "Suns" from 5 mm to the size of a baseball (~75 mm) and the relative diameters of planets, moons and the Sun.

References: [1] Econ. and Stat. Admin. (2011) Brief #03-11. 3, 10. [2] Pres. Coun. of Advisor. on Sci. and Tech. (2012): Washington.[3] NASA Office of Education (2014) *About NASA's Education Program*. Available from: <http://www.nasa.gov/about/contact/index.html#>. USDsLiim 40. [4] Huang and Soman, (2013), *A Practitioner's Guide To Gamification Of Education*, University of Toronto.

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Earth's Volcanoes
There are many different types of volcanoes and volcanic eruptions. Some volcanoes erupt more violently than others, and some more frequently than others

Type	Characteristics	Examples	Sketches
Fluxure or Flood	Very liquid lavas flow from fissures or fractures	Columbia River Plateau, Washington, Oregon, and Idaho	
Cinder Cone	Explosive lavas cool in the air to fall down as cinders, eventually building a cinder cone.	Mount Tabor, Oregon	
Composite or Stratovolcano	Can erupt more viscous (thicker) lavas or explosive pyroclastic debris.	Mount St. Helens and Mount Hood, Washington	
Caldera	Very large composite volcano with a caldera resulting from collapse after an explosive period.	Crater Lake, Newberry Caldera	
Shield	Erupt thin flowing basalt lavas that eventually build into a broad cone.	Hawaiian Volcanoes	

COMMON TYPES OF ERUPTIONS

Basic Volcano Features

- Magma chamber:** Molten rock, gases, and superheated water.
- Central vent:** During an eruption magma, gasses, water and debris flow up the central vent. Other vents can branch off the central vent and lead to eruptions along the flanks of the volcano.
- Crater:** This is a depression at the top of the volcano where the main vent erupts.
- Eruption column:** The lower eruption column is powered by gasses and water vapor thrusting from the central vent. Higher up in the column convective thrust takes over powered by the heat of the erupted gasses. The more gasses and water in the magma, the higher the column can be.
- Downwind plume:** Hot gasses and pyroclastic material (such as pumice, ash, and tiny pieces of volcanic rock) can reach many tens of thousands of feet into the atmosphere. The materials is then carried by the wind away from the volcano as a plume.
- Fallout:** as the gasses cool, ash and other tiny debris fall from the plume to the ground as ash falls. Ash falls can create deposits on the surface that are meters thick.
- Lava Flows:** When magma comes to the surface it is called lava. Lava can flow down the flanks of a volcano and beyond and threaten anything in its path. There are two common types of lava, 'A'a (pronounced "ah-ah") and pahoehoe. 'A'a flows are slow moving and produce clumpy or ropey deposits. Pahoehoe flows can flow very fast, up to 60 km/h (40 mph).
- Lahar:** Lahars are debris flows consisting mainly of pyroclastic materials and water. They occur when part of the volcano collapses. They can travel over 95 km/h (60 mph). They look like muddy rivers but the material flowing in them is more dense than concrete. They follow topography and can be very dangerous to any towns in their path.
- Pyroclastic flows:** These are quickly flowing clouds of ash and fine particles that can happen during an active eruption. They flow with gravity down the sides of volcanoes but do not follow topography. They can move as fast as 700 km/h (450 mph). They are very dangerous and can bury entire towns!

Solar System Volcanoes
Earth is not the only place volcanoes form. Venus and Mars both have volcanoes, and Mercury probably does as well. A number of moons, including Jupiter's moon Io and Saturn's moon Enceladus, have volcanoes.

Olympus Mons on Mars (left) is the largest known volcano in the solar system. This volcano is about 600 km (373 mi) in diameter and 24 km (15 mi) tall. It's so large it would not fit within the borders of Nevada!

Jupiter's moon Io (right) is the most volcanically active body in our solar system. The yellow color of the moon comes from sulfur erupted to the surface from many active volcanoes. The Voyager 1 spacecraft caught an image of an active eruption on the horizon of the Io (blue plume in boxed image).

Enceladus is one of Saturn's moons and has cryo-volcanism. In the image on the left you can see active cryo-volcanoes erupting mainly water from the southern hemisphere. It is thought that under the icy surface there is an ocean.

RESOURCES AND ACKNOWLEDGEMENTS:
More information can be found at volcanoes.usgs.gov, and photojournal.jpl.nasa.gov. Poster by C. T. Adcock. This material is based upon work supported by the National Aeronautics and Space Administration under Grant No. NNX10AN23H issued through Nevada Space Grant.

Figure 3. Scaled down image of planetary volcanoes poster used as part of the Volcanoes in the Solar System event.