GENERATING STEAM WITH ENGAGING LUNAR EXPLORATION EDUCATION / PUBLIC OUTREACH ACTIVITIES. C.J. Runyon[1], C. Hall[1], E. Joyner[1], H. Meyer[1], D. Daou[2], D. Hurd[3], K. Boyce[4], K. Garver[4]; [1]Geology, College of Charleston, Charleston, SC, runyonc@cofc.edu , [2]NASA Lunar Science Institute, doris.daou@nasa.gov, [3]Edinboro University of Pennsylvania, Edinboro, PA, dhurd@edinboro.edu, [4]Montana State University, Bozeman, MT, kboyce@montana.edu

Introduction: With the growing need for a scientifically-trained workforce, lunar exploration plays an important role in encouraging students to pursue science, technology engineering and/or math (STEM) careers. Many of NASA's lunar educational materials do not effectively address 21st Century skills or cross-curricula opportunities, essentials for today's learning environment. Here, we present a model in lunar science education professional development that is replicable and sustainable and integrates NASA mission-derived data (e.g., Moon Mineralogy Mapper (M^3)/ Chandrayaan-1; NASA Lunar Science Institute (NLSI)) into science, math and fine art curricula. In so doing, the M^3 and NLSI Education / Public Outreach (E/PO) program is helping to convert STEM to STEAM (science, technology engineering, arts and mathematics).

Using Authentic Data in the Classroom: To engage and encourage student participation, we integrate authentic mission data into lesson plans. Recent science discoveries from M^3 and NLSI team members (e.g., presence of OH and H_2O on the Moon) also help make the Moon an ideal focus for STEAM-based educational materials and programs.

Moon Mineralogy Mapper (M^3) was one of 11 instruments onboard India's Chandrayaan-1 (Ch-1) spacecraft launched on October 22, 2008. M^3, a high spatial and spectral resolution spectrometer, mapped the compositional variation of the Moon's surface.[1] Analyses of the M^3 mineralogy maps revealed the presence of water and spinel on the lunar surface, generating a renewed vigor and excitement among the science team, lunar community and general public.

NASA Lunar Science Institute (NLSI). We are part of the Brown-MIT NLSI team that focuses on better understanding fundamental, compositional and physical properties of the lunar interior and exterior structures.

Lunar Education & Public Outreach Activities.

Through our E/PO activities and programs we present the ongoing story of lunar exploration and discovery and help teachers engage students in learning how the Moon and planetary surfaces form, and to understand how scientists and engineers explore remote worlds. Our E/PO activities and programs are well-rooted in the national standards in science, math and engineering and are are inquiry-rich. For example, with the M^3 and NLSI resources and activities, learners may answer such questions as: *Why go to the Moon?… What is the benefit (to me) of lunar exploration?... What are new lunar discoveries?...How is the Moon similar to/different from the Earth?... How do other cultures and societies view the Moon?* Resources have been reviewed by teachers for content and usability.

Our E/PO program promotes STEAM literacy using the excitement of the success of Chandrayaan-1 and the discoveries of M^3 and the Brown-MIT NLSI node.[2, 3] The outreach activities and materials highlight not just science, engineering, math, and technology but also how they may be incorporated in the arts. Examples include but are not limited to artistic drawings of the features and changing 'faces' or phases of the moon.

Figure 1: *From the Moon* exhibit.

From the Moon Exhibits: To address more diverse audiences, a unique partnership among the College of Charleston's School of Science and Math and the School of the Arts showcases lunar observations and analyses. *From the Moon: Mapping and Exploration* opened in November, 2011. *From the Moon: Mysteries and Myths* exhibit at the Halsey Gallery of Art in Charleston, SC will open Fall, 2013. Patrons will explore historic and rare artifacts, including a display sample from Apollo 15 and uncommon lunar meteorites.The exhibits also include early observations from Galileo to M^3 and current observations from ongoing NASA lunar missions, such as GRAIL. Both exhibits are/will be paired with tactile activities, lesson plans

and professional development opportunities. Lesson plans are multidisciplinary, including standards not only in science and math but also in the fine arts and history. They have also been vetted with teachers specializing in working with students with unique learning styles and/or special needs.

Getting a Feel for Lunar Craters: Through NLSI, the tactile book, *Getting a Feel for Lunar Craters*[4], was published to allow persons who are blind/visually impaired to experience the excitement of lunar exploration. The book provides tactiles of various types of lunar craters, text descriptions and other resources in multiple formats and was showcased to the California School for the Deaf and Blind, through a hands-on workshop, and the National Federation of the Blind. A second tactile book is in the works, focusing on the composition of the lunar surface.

Figure 2: *CA School for the Blind student getting a feel for lunar craters. Students utilized dental amalgam to generate the model.*

Online Educator Guide: With the return of high resolution/high spatial data from M^3/Chandrayaan-1, we can now better explore and understand the compositional variations on the lunar surface. Data and analysis techniques from the M^3 imaging spectrometer are incorporated into the M^3 Educator's Guide: *Seeing the Moon in a New Light*[5, 6]. The guide includes an array of activities and lessons to help educators and students understand how NASA is currently exploring the Moon. The guide integrates NASA maps and data into the interactive lessons, bringing the excitement of scientific exploration and discovery into the classroom. The M^3 Educator's guide includes eight new activites written for upper elementary school – middle school. Activities examine spectroscopy, lunar geology, surface morphology and composition. Students use an ALTA hand-held spectrometer to identify and map compositional variation on the moon's surface. From these measurements, the students discover that the Moon is similar to, yet different from, the Earth and terrestrial planets. Through NLSI, we are utilizing existing content to develop interactive SMARTBoard lessons and an educational module in Google Moon.

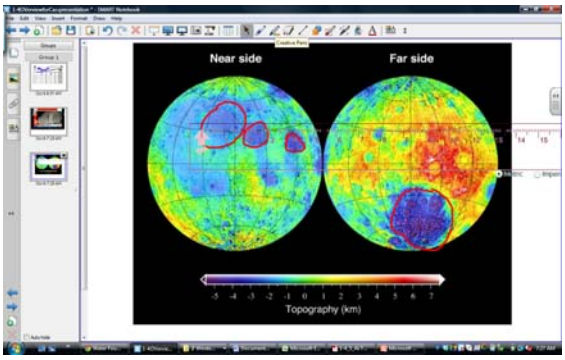

Figure 3: *Example of measuring lunar impact features on the SMARTBoard.*

On-line Learning Resources: Utilizing educational activities from M^3 and more current NASA lunar missions, we offer two sustained professional development opportunities for educators to explore the Moon through interactive and creative strategies. 1) *Geology of the Moon*, an online course offered through Montana State University's National Teacher Enhancement Network and, 2) *Fly Me to the Moon*, offered through the College of Charleston. Through these courses we incorporate interactive ways for educators to work through inquiry-oriented lessons to gather information and data directly through the Internet.

M^3Educator Tool Kits: Included in the kits are activities and resources related to the current Chandrayaan-1 mission, the M^3 instrument, spectroscopy and more. The kits were created for use in workshops and classrooms. These kits may be useful for future mission EPO programs such as Lunar Reconnaissance Orbiter (LRO), LADDIE, and the NLSI.

References: [1] Pieters et al. (2009) Science, vol 326, pp 568-572; [2] Pieters et al (2011) JGR 116, E00G10; [3] Isaacson et al (2011) JGR 116, E00G11; [4] NASA Headquarters, NP-2011-05-733-HQ [5] Runyon et al (2011) M3S2 Conference abstract; [6] Runyon et al (2011), PLANEX Conference abstract.

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