PLANETS: Planetary Learning that Advances the Nexus of Engineering, Technology, and Science: A Subject Matter Expert View of Curriculum Development. M. P. Milazzo; R. Anderson; L. Edgar; T. Gaither; R.G. Vaughan. USGS Astrogeology Science Center; (moses@usgs.gov)

Introduction Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (PLANETS) was selected as one of 27 new projects to support the NASA Science Mission Directorate's Science Education Cooperative Agreement Notice. Our goal is to develop and disseminate out-of-school time (OST) curriculum and related educator professional development (PD) modules that integrate planetary science, technology, and engineering. We operate as a partnership between planetary science Subject Matter Experts (SMEs), curriculum developers, science and engineering teacher professional development experts and OST teacher networks. The PLANETS team includes the Center for Science Teaching and Learning (CSTL) at Northern Arizona University (NAU); the U.S. Geological Survey (USGS) Astrogeology Science Center (Astrogeology); and the Boston Museum of Science (MOS). As part of this overarching project, we will create a model for improved integration of SMEs, curriculum developers, professional development experts, and educators during all stages of curriculum development.

Curriculum to be Developed Here, we present the work and approach by the SMEs at Astrogeology. For the 2016 and 2017 Fiscal Years, our focus is on creating science material for two OST modules designed for middle school students. We will begin development of a third module for elementary school students in the latter part of FY2017. The two modules will be tested and refined based on educator and student feedback, with expected final release in late summer of 2017 (around the beginning of the 2017-2018 school year).

Testing the Waters The first module focuses on water conservation and greywater treatment as applied on Earth, the International Space Station, and at a fictional Mars base, as well as accessibility of water throughout the Solar System. This unit involves the science and engineering of finding accessible water, evaluating it for quality, treating it for impurities (i.e., dissolved and suspended, organic and inorganic), initial use, a cycle of greywater treatment and re-use, and final treatment of blackwater. In this unit, students will be introduced to engineering and an eight-step Engineering Design Process. They will explore the problem of water scarcity on Earth and in space, and learn how to test water quality. Then, they will engineer greywater systems that will filter recycled greywater to make it safe and clean enough for planetary explorers to drink. By the end of the unit, they will be ready to present what they learned about systems engineering and the Engineering Design Process by sharing the greywater systems that they have engineered.

Worlds Apart The second module involves the science and engineering of remote sensing as it is related to Earth and planetary exploration. This includes discussion and activities related to the electromagnetic spectrum, spectroscopy and various remote sensing systems and techniques. In these activities and discussions, we include observation and measurement techniques and tools as well as collection and use of specific data of interest to scientists. In this unit, students will be introduced to engineering and an eight-step Engineering Design Process as they work together to engineer remote sensing devices for partner scientists. They will investigate different remote sensing technologies — telescopes, light filters, and LiDAR — before engineering their own remote sensing devices to solve one of the research problem posed by the scientists. By the end of the unit, they will be ready to present what they learned about remote sensing and the Engineering Design Process by sharing the engineering work they have done.

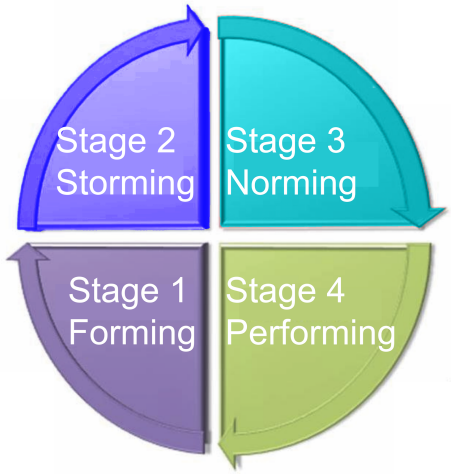

Figure 1: *The four stages of group dynamics.*

PLANETS Team Development Professional STEM educators (who teach students in STEM disciplines, teach teachers how to teach, and develop STEM curricula), and scientists (who are actively doing scientific research, and rely on the public support of science and the proper education of the next generation) are all on the same team and have similar goals: inspiring and engaging the next generation of scientists, engineers, and explorers, and increasing public science literacy. However, we view the game from different perspectives. We have

a different language, different time lines, different expectations, different backgrounds and experiences, and different ideas. So, an interdisciplinary partnership between planetary scientists who are devoted to STEM education; and professional STEM educators, curriculum developers, and teachers who are eager to incorporate modern cutting-edge science into their STEM curricula can be as challenging as it is valuable. This project has been fun, interesting, challenging, as well as an exercise in the stages of group development [1].

Figure 2: *Engineering Habits of Mind.*

Concluding Remarks During the development of the team, we noticed an interesting coincidence: there appears to be a parallel between the names of the curricular units we are working on, and the nature of the collaborative relationship between the SMEs and the STEM education professionals. There is also an interesting parallel between the stages of group development (Fig 1), the engineering design process (Fig 2, and the methods of science (Fig 3) — in that, these human endeavors are essentially identical in how they progress. Much like the scientific process of testing hypotheses and predictions,

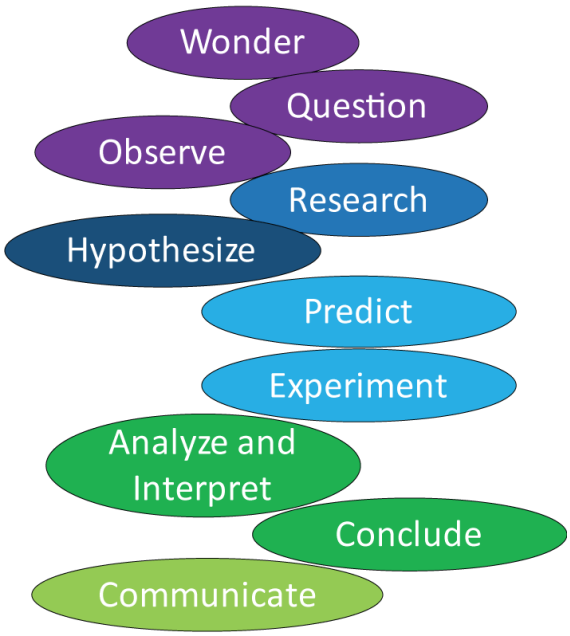

Figure 3: *The methods of science.*

or the engineering process of testing a design, the group process of storming and norming iteratively cycles between trying something that at first may not work, and trying variations until something does work. Other important lessons learned include:

- Face-to-face meetings are critical to effecient human interaction and communication, understanding group dynamics, and developing a mutual understanding of shared goals
- Electronic file sharing is useful, but clunky no matter what application is used
- Observing the engineering education modules tested in real time by teachers and students is critical to understanding the OST environment
- We absolutely could not do this right without the collaborative and camaraderie we have built over the past year.

References: [1] Tuckman, BW. *Psychological bulletin*, 63:384 (1965).