PLANETARY SCIENCE CURRICULAR AND PROFESSIONAL DEVELOPMENT MATERIALS FOR OUT-OF-SCHOOL-TIME EDUCATORS. N. G. Barlow[1] and J. G. Clark[2], [1]Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011 Nadine.Barlow@nau.edu, [2]Center for Science Teaching and Learning, Northern Arizona University, Flagstaff, AZ 86011 Joelle.Clark@nau.edu.

Introduction: Out-of-School-Time (OST) activities are utilized by an increasing number of K-12 students and are an excellent venue to provide additional exposure to the STEM fields. The Center for Science Teaching and Learning (CSTL) and the Department of Physics and Astronomy (P&A) at Northern Arizona University (NAU) have joined with the US Geological Survey Astrogeology Science Center (USGS ASC) and the Boston Museum of Science (MoS) on a project to develop OST curricular units and professional development materials related to planetary science themes. Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (PLANETS), is a five-year NASA-funded project to integrate planetary science, technology, and engineering concepts into units for elementary and middle school youth.

Curricular Materials: Planetary scientists at USGS ASC and P&A have developed two units for middle school youth and one for upper elementary aged youth. The two middle school units focus on greywater recycling and remote sensing of planetary surfaces while the elementary unit centers on exploring space hazards (Fig. 1). All units are designed for small teams of ~4 youth to work together to investigate materials, engineer tools to assist in the explorations, and utilize what they have learned to solve a problem. Youth participate in a final share-out with adults and other youth of what they learned and their solution to the problem.

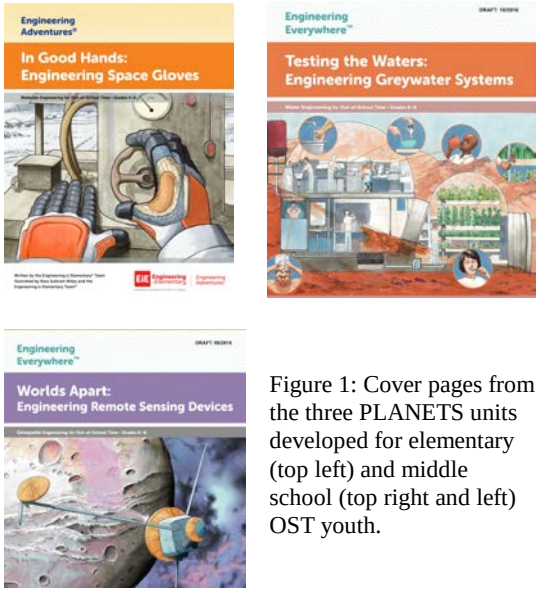

Figure 1: Cover pages from the three PLANETS units developed for elementary (top left) and middle school (top right and left) OST youth.

The project began in January 2016 with USGS scients brainstorming possible ideas for the science contents of the middle school units [1, 2]. A unique aspect of this project is the partnership between subject matter experts (SMEs), curriculum matter experts (CMEs), and professional development experts (PDEs) in the development of the materials. All partners have met face-to-face once per year, but monthly telecons are held between the group leaders, quarterly telecons are held among all partners, and the individual groups meet more frequently. Occassional small group meetings are held to test the hands-on activities ("mess-arounds") and obtain feedback from others. The USGS ARC SMEs have worked closely with MoS CMEs to develop the curricular materials, which are part of the MoS's successful Engineering Adventures and Engineering Everywhere programs for OST groups. Each unit leads youth through steps of an engineering design process, shown in Figure 2 for middle school-aged youth.

Figure 2: Figure of the Engineering Design Process utilized by middle school PLANETS units. The visual use of gears in this diagram helps youth to understand how each step is interconnected with and driven by others.

NAU P&A SMEs and CSTL PDEs then review the student notebooks and educator guides and provide feedback on changes, extension activities, etc., which the USGS ASC SMEs and MoS CMEs use to revise the units. This process is repeated at least twice before pilot testing is conducted with educators and youth across the US. Input from those pilot studies lead to another round of revisions. This iterative process in-

volving SMEs, CMEs, PDEs, and educators ensures that the materials are scientifically accurate, contain clear objectives and easy-to-follow directions, meet the needs of the educators, and engage youth in designing and testing solutions to challenging problems relevant to space exploration.

Alignment with National STEM Goals: The materials are designed to ensure alignment of the PLANETS project with documented planetary science goals as defined by the Planetary Science Decadal Survey [3], the 2014 NASA Science Plan [4], and the Mars Exploration Program [5]. PLANETS activities specifically address the following themes:

1. From the Decadal Survey [3]:
    a. Searching for the requirements of life
    b. Revealing planetary processes through time.
2. From the 2014 NASA Science Plan Planetary Science Goals [4]:
    a. Explore and observe the objects in the solar system to understand how they formed and evolve.
    b. Advance the understanding of how chemical and physical processes in our solar system operate, interact, and evolve.
    c. Explore and find locations where life could have existed or could exist today.
    d. Identify and characterize objects in the solar system that pose threats to Earth or offer resources for human exploration.
3. From the Mars Exploration Program goals and objectives:
    a. Prepare for human exploration

The materials also are designed to address the national goals of the 2013 Federal STEM Education 5-Year Strategic Plan [6]:

1. Improve STEM Instruction through professional development for OST educators
2. Increase and sustain youth and public engagement by providing engaging STEM content for OST experiences.
3. Better serve historically under-represented groups in STEM fields by focusing efforts for dissemination of materials in areas serving underrepresented students.

The last bullet item is addressed in the PLANETS project by involving educators from the Navajo and Hopi reservations in northern Arizona in the pilot testing. The curriculum also has been developed to support the National Research Council's Next Generation Science Standards [7].

Professional Development and Research: A major component of the PLANETS project is to produce professional development (PD) materials for the OST educators to enhance their knowledge of planetary science and engineering and to facilitate their confidence in guiding the youth during the activities. CSTL has conducted a needs assessment nationwide among educators and is obtaining feedback from the educators involved in the pilot testing. One result of the needs assessment is that more than half of the OST professionals participate in 0-5 hours of PD on STEM content each year. Obviously STEM PD support for OST professionals is an area of need.

As a result, the project is developing and testing four tiers of professional support for OST educators.

- Tier 1 meets the immediate needs of OST educators to teach curriculum and includes how-to videos and other direct support materials.
- Tier 2 provides additional content and pedagogical knowledge and includes short content videos designed to specifically address the content of the curriculum.
- Tier 3 elaborates on best practices in education and gives guidance on methods, for example, to develop cultural relevancy for underrepresented students.
- Tier 4 helps make connections to other NASA or educational products that support STEM learning in OST settings.

Conclusions: Our research has revealed that STEM-related PD support for OST professionals is an area of need that we are working to help fill with the PLANETS project. In addition, the partnership of SMEs, CMEs, and PDEs and the iterative process in the development, review, revision, and testing of the materials capitalizes on the strengths of each group and leads to thorough vetting of the resulting materials. Such partnerships are important in the development of accurate and usable STEM materials.

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