Evaluation of the NASA-Funded Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (PLANETS) Project

5-Year Summative Evaluation Report

Principal Investigator: Joelle Clark
Northern Arizona University

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PLANETS

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Executive Summary

Beginning in January 2016, the National Aeronautics and Space Administration (NASA) funded 27 organizations across the U.S. to implement education and public outreach programs around four themes: heliophysics, earth science, planetary science, and astrophysics. As part of this Science Activation (SciAct) effort, NASA awarded an initial 5-year cooperative agreement to the Center for Science Teaching and Learning (CSTL) at Northern Arizona University (NAU) for the project Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (PLANETS).

PLANETS involved a collaboration between CSTL, the U.S. Geological Survey (USGS) Astrogeology Science Center, and the Museum of Science, Boston (MOS) to provide out-of-school-time (OST) educators and youth with current, relevant, and engaging planetary science content delivered through science and engineering activities that integrate new and existing NASA assets. Summatively, evaluators examined the extent to which the PLANETS project met its four main objectives: (a) modeling an interdisciplinary partnership to create high-quality curricular materials, (b) developing nationally available curricular units to reach underserved populations, (c) creating useful educator resources to support implementation of the units, and (d) disseminating PLANETS products and research findings to a national audience.

NAU contracted with Magnolia Consulting, LLC, a research and evaluation company, to conduct an external evaluation of the project. The purpose of the evaluation was to understand how the PLANETS project was implemented and assess the impacts of participation on project collaborators, OST providers, and OST learners.

Study Design and Methods

Evaluators conducted formative and summative evaluations of PLANETS using a mixed-methods approach. The formative evaluation assessed program processes to understand how well the partnership model was working to achieve the project's goals, the delivery of activities, the quality and utility of the materials produced, and the degree to which activities were implemented as planned. In addition, the formative evaluation tracked the project's progress in addressing NASA's top-level science education objectives. The summative evaluation in Years 4 and 5 examined the impacts of fully developed PLANETS units on a sample of participating OST educators and youth. The summative evaluation also examined the impact of participating in PLANETS on the individuals and organizations involved in the partnership and examined the extent to which the project supported NASA's top-level objectives.

Participants

PLANETS Partners

- NAU PI, Co-PI, researchers
- USGS scientists
- MOS curriculum developers and researchers

OST educators and youth in pilot, research, and field test sites

Summative Measures

- Document review
- Partner surveys and interviews
- Meeting observations
- Educator implementation and educator knowledge and skills surveys
- Educator interviews
- Youth engineering interest and attitudes survey

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Model an interdisciplinary partnership between planetary subject matter experts (SMEs), OST curriculum developers, science and engineering professional development experts, and OST networks, merging diverse expertise in a synergistic, sustainable, and productive relationship.

With respect to the interdisciplinary partnership, the PLANETS team overcame early challenges related to communication, roles, and responsibilities to become a highly functioning collaborative partnership with a shared vision for the work and a sense of unique purpose. Across all years of the project, partners consistently noted that the work of creating and disseminating the units and educator resources could not have been done by one of the partner organizations alone. The diversity and particular areas of expertise of each partner organization were necessary to accomplish the project goals. The health of the partnership was evident as the team responded to COVID-19 program closures and the emerging new needs of families and educators during the pandemic. Had the pandemic-related obstacles occurred at an earlier stage of the partnership, the partners may not have had the cohesiveness to respond as effectively as they were able to with years of sustained and productive collaboration in place.

Key Partner Impacts

- ✓ Working on a national-level, NASA-funded project increased organizational visibility.
- ✓ Learning from others outside of partners' areas of expertise increased individual and organizational learning.

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Develop curricular units and novel ancillary materials appropriate for OST contexts nationally by integrating new and existing NASA assets, planetary science content, and engineering processes and habits of mind. PLANETS research on curriculum implementation focused on student attitudes toward engineering, particularly among youth from populations that are underrepresented in STEM fields.

Over the course of the project, the PLANETS team met its goal of creating three curricular units—two for middle school youth and one for elementary youth—that were designed to reach educators and youth in out-of-school-time environments. Understanding that OST environments differ from formal classroom environments, the team built upon knowledge in the field and on partner expertise to design materials targeted to youth in afterschool or summer programs. Educators and project partners noted the need for materials to be engaging, so that the curriculum didn't "feel like school" and made STEM learning fun while simultaneously building skills and interests.

Youth Interest & Attitudes

- ✓ Youth interest and attitudes toward science and engineering significantly increased as a result of participating in PLANETS.
- ✓ OST educators' perceptions of students' learning and engagement with the materials leaned toward the positive.

When enacted in pilot and field test sites, PLANETS lessons engaged students in engineering habits of mind, helping them learn to persist through failure and to work collaboratively to solve an engineering challenge. Youth in pilot and field test sites showed statistically significant increases in positive attitudes toward engineering as a result of their participation, suggesting that using an engineering design process involving collaboratively designing a solution to a challenge, testing the solution, and revising their design is an effective way to engage students in STEM learning. Educators also gained in their understanding of STEM content and instructional practices through participating in the curriculum.

3 Create educator resources designed for self-directed learning that support OST educators in implementing program materials effectively, and collect evidence of resource use by educators. PLANETS research on resource implementation focused on the degree to which the educator resources helped prepare OST educators to teach the curricular products.

Educator resources were developed and shared via the planets-stem.org website, and the team continues to revise and improve them. The PLANETS team is using formative feedback from field test sites to make the resources easier to access by tying them to individual lessons in the units. Use of educators to co-create the resources through educator workshops helped to ensure that the resources were useful to the targeted audiences. The team utilized NASA assets such as subject matter experts, videos, images, and data as a means of engaging learners in the units and providing exciting supplementary content for learners.

4 Widely disseminate (a) curricular and educator resources designed to increase access to and use of NASA assets, with particular attention to reaching underrepresented populations, and (b) knowledge regarding teaching and learning practices in OST activities gained as a result of the project.

With respect to disseminating the curriculum and research findings to a national audience, PLANETS exceeded its original goals. Through workshops, pilot and field tests, and outreach, more than 2,500 adults and 3,000 youth were directly reached through the project, and tens of thousands of others were potentially reached through downloads of the materials. Development of the PLANETS website, and links to the engineering guides on the MOS website, ensure sustainability of the materials over the years. Additionally, the team disseminated PLANETS products, and research and evaluation findings via national and state conferences, community outreach, and educator workshops.

PLANETS Downloads	Total Downloads 2018–2020
Remote Sensing	1,581
Water in Extreme Environments	2,969
Space Hazards	948
Total downloads	5,498

Contribution to Knowledge

- ✓ Youth engage in certain engineering habits of mind through engagement with the engineering design process.
- ✓ Educators need resources that are targeted to their immediate needs.
- ✓ Educators need support for understanding the processes of science and engineering.
- ✓ Curriculum developers must consider OST contexts to develop useful and effective curricula for OST programs.

PLANETS leveraged community partners in northern Arizona, a statewide afterschool network in Arizona, and collaborations with other SciAct partners to help broaden the reach of the project. Additionally, a unique feature of PLANETS was to use NASA SMEs directly in development of the resources, which helped to ensure their accuracy and increased access to appropriate NASA assets.

Addressing NASA's Top-Level Objectives for Education

NASA's Science Mission Directorate seeks to integrate NASA assets into science education. The top-level objectives for this effort are:

- Enabling STEM education
- Improving U.S. scientific literacy
- Advancing national education goals
- Leveraging efforts through partnerships

The SciAct initiative was designed to support these objectives, and evaluators tracked the PLANETS project's contributions to NASA's objectives.

PLANETS Contributions to Key Top-Level NASA Objectives

✓ 1: Contributed to enabling STEM education by creating, testing, and disseminating 3 curricular units, directly reaching over 5,000 educators and youth and potentially reaching 30,000+ more through materials downloads.

✓ 2: Demonstrated that youth showed statistically significant increases in engineering interest and attitudes from participating in PLANETS units. Educators showed growth in science and engineering knowledge and skills from using the materials.

✓ 3: Increased public engagement in STEM through NASA-themed curricular units and at-home activities reaching thousands of educators and youth and the public through direct and indirect outreach, social media, conferences, and workshops.

✓ 4: Leveraged expertise of organizational partners in development and dissemination.

In January 2021, PLANETS was awarded a 5-year extension (PLANETS 2.0), with a focus on enhancing the materials and educator resources to make them more accessible and useful to more diverse audiences, including youth with physical disabilities, English learners, and Native American youth. The team is committed to incorporating lessons learned from PLANETS 1.0 to ensure a collaborative and effective partnership for continued work.

Acknowledgments

Magnolia Consulting wishes to thank the PLANETS partners from the Center for Science Teaching and Learning; the Museum of Science, Boston; and the U.S. Geological Survey for being so responsive to data collection requests across the years and for providing invaluable feedback to inform our recommendations and conclusions. We also wish to thank the out-of-school-time educators and youth who participated in the unit field studies for implementing the units and participating in data collection requests. Finally, we wish to thank Joelle Clark, PLANETS principal investigator, for her continued collaborative approach to evaluation, and the PLANETS team for responding to our data-based recommendations across the years.

The authors,

Carol Haden, EdD
Principal Evaluator

Beth Peery, MA
Researcher/Evaluator

Magnolia Consulting, LLC
5135 Blenheim Rd.
Charlottesville, VA 22902
855.984.5540 (toll free)
www.magnoliaconsulting.org

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Introduction

Beginning in January 2016, the National Aeronautics and Space Administration (NASA) Science Mission Directorate (SMD) established Science Activation (SciAct) collaborative funding organizations across the U.S. to implement education and public outreach programs around four themes: heliophysics, earth science, planetary science, and astrophysics. SciAct was intended to further SMD top-level objectives to:

- Enable STEM education in all 50 states
- Improve U.S. scientific literacy
- Advance national education goals
- Leverage efforts through partnerships

As part of this funding effort, NASA awarded a 5-year cooperative agreement to the Center for Science Teaching and Learning (CSTL) at Northern Arizona University (NAU) for the project Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (PLANETS). NAU contracted with Magnolia Consulting, LLC, a research and evaluation company, to conduct an external evaluation of the project. The purpose of the evaluation was to understand how the first 5 years of the PLANETS project (PLANETS 1.0)[1] was implemented and assess the impacts of participation on project collaborators and out-of-school-time (OST) educators and learners.

The evaluation process included both formative (implementation) and summative (impact) evaluations. The formative evaluation apprised project staff on progress toward intended outcomes to inform development, planning, and modifications to program activities. The summative evaluation assessed the degree to which the project met its goals of creating (a) high-quality curricula and educator resources for OST programs and (b) an effective partnership model for science education.

Program Description

The PLANETS project (Figure 1) is an innovative, collaborative partnership to develop OST modules and educator resources that integrate planetary science, technology, and engineering. OST modules target upper elementary and middle school learners, with a special emphasis on underrepresented populations. CSTL at NAU; the U.S. Geological Survey (USGS) Astrogeology Science Center; the Museum of Science, Boston (MOS); and STEM City in Flagstaff, AZ, sought to provide youth and educators with current, relevant, and engaging planetary science content delivered through OST science and engineering activities that integrate new and existing NASA assets. Additional tangential partners on the project included NAU's Institute for Tribal Environmental Professionals (ITEP), which helped connect the project to Native American

Figure 1. PLANETS project logo

[1] PLANETS was awarded a 5-year extension beginning January 1, 2021. The first phase is referred to as PLANETS 1.0, and the new phase as PLANETS 2.0.

schools; OST program providers (e.g., Arizona Center for Afterschool Excellence [AzCASE]); the Lowell Observatory; and SciAct partners.

The goal of PLANETS is to increase public awareness and use of NASA education resources by highlighting the synergistic relationships between science, technology, engineering, and mathematics (STEM) in planetary science. To address this overarching goal, the PLANETS 1.0 project had the following four objectives.

1	Model an interdisciplinary partnership between planetary subject matter experts (SMEs), OST curriculum developers, science and engineering professional development experts, and OST networks, merging diverse expertise in a synergistic, sustainable, and productive relationship.
2	Develop curricular units and novel ancillary materials appropriate for OST contexts nationally by integrating new and existing NASA assets, planetary science content, and engineering processes and habits of mind. PLANETS research on curriculum implementation focused on student attitudes toward engineering, particularly among youth from populations that are underrepresented in STEM fields.
3	Create educator resources designed for self-directed learning that support OST educators in implementing program materials effectively, and collect evidence of resource use by educators. PLANETS research on resource implementation focused on the degree to which the educator resources helped prepare OST educators to teach the curricular products.
4	Widely disseminate (a) curricular and educator resources designed to increase access to and use of NASA assets, with particular attention to reaching underrepresented populations, and (b) knowledge regarding teaching and learning practices in OST activities gained as a result of the project.

A logic model linking program activities to intended outcomes is presented in Appendix A.

Evaluation Design

External evaluation of the PLANETS project utilized multiple data collection methods and included both qualitative and quantitative measures to ensure that findings were as rigorous as possible (U.S. General Accounting Office, 1990; Wilkerson & Haden, 2014; Zucker, 2009). Evaluators triangulated findings from qualitative and quantitative data sources to provide a more comprehensive understanding of program implementation and outcomes than could be obtained from either source alone (Creswell & Plano Clark, 2007; Patton, 2015).

Formative evaluation allows for a continual feedback process wherein data are collected on program development and implementation to support programmatic improvement along the way (Fitzpatrick, Sanders, & Worthen, 2004). Formative evaluation helps project staff to understand the strengths and weaknesses of an approach under actual conditions of implementation so that the implementation can be strengthened as it proceeds (Stufflebeam, 2003). For this project, formative evaluation included an evaluation of program processes to understand how well the partnership model worked toward achieving the project's goals. Formative evaluation also examined how activities were delivered, the quality and utility of materials produced, and the degree to which activities were implemented as planned. The formative evaluation was conducted in Years 1–4, and each year, evaluators provided recommendations for programmatic improvement in the annual evaluation report. The following questions guided the formative evaluation.

Formative Evaluation Questions

1. Are project partners meeting benchmarks for project development and implementation?
2. How well are partnerships working toward meeting project objectives?
3. What external factors are influencing project development and implementation?
4. What is the quality of materials produced through the project?
   a. How well are the curricular materials produced by the project aligned to NASA science education goals and to the Next Generation Science Standards and the National Research Council's K–12 Framework?
   b. To what extent are NASA assets integrated into the curricular materials?
5. How well do educator resources support educators in implementing the units?
6. To what extent and in what way do participating OST providers implement the units in their programs?

The summative evaluation examined the effects of the fully developed units on a sample of participating OST providers and youth; this work extended the research and evaluation conducted earlier in the project. The following questions guided the summative evaluation.

Summative Evaluation Questions

1. Did the project meet its objectives to create high-quality curricula and educator resources for OST programs, through an effective partnership model for science education?
2. What were the impacts of the partnership on project partners and their institutions?
3. Did the program reach the target audience for the materials developed?
4. Did youth show more positive attitudes toward science and engineering as a result of participating?
5. Did youth show the ability to engage in targeted engineering habits of mind as a result of participating?
6. Did OST providers who used the educator resources increase their knowledge and skills related to the unit content and pedagogies?
7. To what extent and in what way did the project contribute to the body of high-quality materials in STEM education?
8. To what extent did the project contribute to knowledge in the field of STEM education?
9. To what extent did the project contribute to NASA's top-level objectives for education?

Activities for this phase of evaluation included examining the effectiveness of the PLANETS 1.0 partnership model in reaching project goals, understanding the effects of the materials on educators and youth in OST programs, and examining lessons learned and contributions to the field. Evaluators also tracked alignment of the PLANETS project to NASA's top-level objectives.

PLANETS Unit Field Tests

As part of the summative evaluation, evaluators conducted field tests for each PLANETS unit in diverse OST programs across the U.S. The field test of the *Remote Sensing* unit was conducted in fall 2019. The field tests for the *Water in Extreme Environments* and *Space Hazards* units, originally scheduled for spring 2020, were postponed due to COVID-19 to fall 2020 and spring 2021, respectively. The field tests were designed to better understand (a) how educators used the curricula and educator resources in their OST settings; (b) how using the materials affected educators' understanding of STEM concepts and teaching strategies; and (c) how participating in the activities affected learners' understanding of the concepts and their interest in engineering. Additionally, these field tests gathered educator feedback on the quality and usefulness of the materials for their learners. Each field test used a treatment-only design utilizing mixed methods.

Evaluators asked educators to participate in approximately 3 hours of online professional development by accessing the educator resources at https://planets-stem.org to learn about the content, materials, and resources for their units. Then educators implemented the unit with their learners in their OST programs. This report includes the findings for the *Remote Sensing* and *Water in Extreme Environments* units. The field test results for the *Space Hazards* unit will be added as in an addendum to this report, since data collection will occur through spring 2021 as part of the delays related to COVID-19.

Participants

Participants in the Year 5 evaluation activities were PLANETS partners from MOS, USGS, and NAU's CSTL and included the project's principal investigator and professional development, research, and evaluation staff from NAU; USGS scientists who served as subject matter experts; and researchers from MOS. The two field tests (the *Remote Sensing* unit and the *Water in Extreme Environments* unit) reached 15 educators across 11 sites and approximately 300 youth.[2] Of these participants, 14 educators and 163 youth were included in the final analysis sample due to challenges with collecting data from two sites during the fall 2019 field test. See Appendix B for more details about the field test analysis samples.

Measures

Evaluators employed a mixed-methods approach to the summative evaluation of PLANETS. Year 5 summative measures included the results of document review (including meeting notes and project planning and implementation documents), partner surveys and interviews, OST educator surveys and interviews, and a student Engineering Interest and Attitudes (EIA) survey. Prior to COVID-19, evaluators were able to observe two OST programs as they implemented the *Remote Sensing* unit. Results from these observations are included in the report. Additional measures included website analytics and dissemination tracking. Through these efforts, evaluators examined partnership health, outreach activities, and dissemination; conducted field tests; and assessed progress toward project milestones. A matrix linking evaluation questions to measures and metrics is presented in Appendix C. Descriptions of all formative and summative evaluation measures are presented in Appendix D.

Analyses

Evaluators entered data from surveys into SPSS 24 to calculate means and frequencies. Open-ended survey items were analyzed using content analysis. Evaluators imported interview transcriptions into Atlas.ti, a computer program that assists in coding qualitative data. Following a thorough review of the data recorded from all sources, evaluators generated a set of preliminary assertions (statements believed to be true based on the complete dataset) regarding the evaluation questions. They then refined the assertions and established whether each was warranted. Researchers ensured that excerpts from the data record supported each warranted assertion and linked the assertions, themes, and findings in a manner designed to support analytic generalization (Glaser, 1978).

The following sections of the report provide summative findings across the project years, including progress toward project objectives, the success of the PLANETS partnership, results from the field tests, and alignment of the project to NASA's top-level objectives.

[2] This estimate includes students of four teachers who did not provide final student data for the study but who did implement the unit, and students who did not complete the EIA. The analysis sample includes only the 163 youth who completed the EIA survey.

Findings Related to PLANETS Objectives

?

Did the project meet its objectives to create high-quality curricula and educator resources for OST programs, through an effective partnership model for science education?

Summatively, evaluators examined the extent to which the PLANETS project met its four main objectives: (a) modeling an interdisciplinary partnership to create high-quality curricular materials, (b) developing nationally available curricular units to reach underserved populations, (c) creating useful educator resources to support implementation of the units, and (d) disseminating PLANETS products and research findings to a national audience. The following sections of the report address the degree to which each of the PLANETS objectives were met.

Objective 1: Model an Interdisciplinary Partnership

The PLANETS project brought together individuals from multiple organizations to work toward a common goal of creating curricular materials and educator resources that leverage NASA assets to enhance student interest in and understanding of planetary science. USGS Astrogeology provided SMEs who contributed critical content expertise. NAU's CSTL provided science/STEM education research and educator resource design expertise, and MOS provided engineering education, curriculum development, and research expertise (Figure 2). Additional partners included Flagstaff STEM City, NAU astronomy faculty, Lowell Observatory, and Arizona Center for Afterschool Excellence (AzCASE).

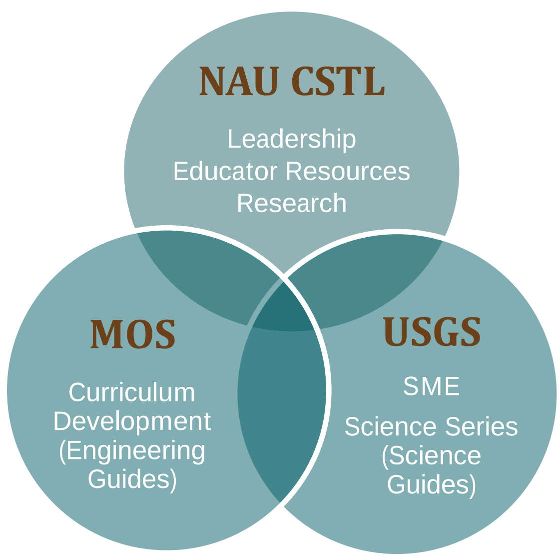

Figure 2. PLANETS key partners and their roles

The following section describes the partnership over the 5 years of the project and then examines the impacts the partnership had on project partners and their institutions.

The PLANETS Partnership

The project's principal investigator and the external evaluator met regularly to plan and monitor progress toward PLANETS outcomes and to discuss modifications for programmatic improvement. Formative findings led to changes in communication procedures and in how roles, responsibilities, and timelines were shared among partners.

With these adjustments, the PLANETS team was able to meet all benchmarks for Objective 1 related to modeling an interdisciplinary partnership to achieve the project goals, including the following (see Appendix E for year-by-year progress toward PLANETS objectives):

- ✓ Annual Partner Working Group meetings
- ✓ Monthly partner check-ins
- ✓ Creation of teams within tasks (e.g., curriculum development, research, dissemination)
- ✓ Site visits between educator resource design, SME, and curriculum partners
- ✓ Project communications and document sharing
- ✓ Use of formative evaluation findings to improve collaboration

To address needs for clearer communication, project leads from CSTL, MOS, and USGS met monthly to share updates on curriculum development, educator resource development, research activities, and planning for the annual Partner Working Group meeting. Team leads then reported back to their teams during regular internal meetings. Additionally, in response to program closures in Year 5 related to COVID-19, project partners met weekly to discuss ways in which the project could provide youth and their families with engaging activities (discussed in in the COVID-19 Implications for Curriculum Development section of this report).

Annual Partner Working Group Meeting

Throughout the project, PLANETS partners valued the opportunity to meet face-to-face as a way of building community and strengthening the partnership. Each fall, the group convened for a 3- to 4-day Partner Working Group (PWG) meeting with team members from MOS, NAU, and USGS, along with the external evaluators. Due to COVID-19, the 2020 annual PWG meeting was held virtually. Previous reports include agendas for the annual PWG meetings, providing more information on the tasks the team undertook (Haden & Peery, 2017; Haden & Peery, 2018; Haden & Peery 2019; Haden & Peery, 2020).

Key PWG Outcomes

- ✓ Formed and strengthened partner relationships for effective collaboration
- ✓ Provided in-depth opportunities to create and strengthen PLANETS products

During the PWG meetings, groups shared progress on unit materials development, worked collaboratively to test unit activities and provide feedback, reviewed findings from the pilot study research and field tests, and strategized about ways to effectively reach the program goals and objectives. At the end of the annual PWG meetings, the partners who had attended provided feedback about the meeting through a survey. Results showed that the majority of participants valued the PWG meeting as a means of moving the work forward and for providing opportunities for the group to engage and collaborate (Table 1). Tables of survey items included in the annual PWG surveys by year are presented in Appendix F.

Table 1. Participant ratings of objectives of the Partner Working Group meeting across years

PWG Meeting Trait	Range of Positive Responses Across 5 Years
Engaging the group in the work of the project	94%–100%
Incorporating multiple perspectives into planning and future work	84%–100%
Developing a shared repertoire of experiences	73%–100%
Creating connections across institutional and geographic boundaries	72%–100%
Moving the work of the project forward	82%–100%
Assessing progress on the project (Years 3–5)[3]	91%–100%
Sharing products/data/lessons learned (Years 3–5)	100%
Promoting a culture of inquiry and collaboration among partners (Years 3–5)	91%–100%
Contributing to and understanding the role of evaluation in PLANETS (Years 4–5)	81%–100%
Initiating a dialogue about moving forward with PLANETS 2.0 (Year 5)	91%

When asked for perceptions of specific aspects of the annual meeting,[4] at least 90% of respondents each year *agreed* or *strongly agreed* that the discussion at the meeting was productive, their contributions to the meeting were valued, and the meeting fostered a sense of community among members. Additionally, at least 80% of respondents each year *agreed* or *strongly agreed* that the meeting was a productive use of time, the meeting fostered clear communication among members, and they had a clear understanding of next steps in their shared work.

> *It is clear that PLANETS has committed partners, which leads to the success of the project. Having a time once a year to celebrate our completed work and re-energize for the upcoming work is a gift.*
>
> *—PLANETS PWG Attendee*

Across all years of the project, PLANETS partners appreciated the opportunity to meet face-to-face for relationship building and for clarifying work, roles and responsibilities, and timelines, and to have concentrated time in small teams to further develop products. Several expressed that the annual PLANETS PWG meeting was a successful strategy for creating cohesiveness among team members.

Partnership Development

Evaluators continuously monitored the health and function of the PLANETS partnership, with a view to maximizing the group's ability to work together effectively to reach project goals. To address the formative evaluation question related to partnership health, evaluators gathered data through surveys, interviews, meeting observations, and document review.

[3] For Year 5, this item also included developing a plan for completing PLANETS 1.0.
[4] Includes all project years except Year 2.

Each year, except for Year 4, PLANETS partners completed an end-of-year survey that utilized items from the Wilder Collaboration Factors Inventory (Mattessich, Murray-Close, & Monsey, 2001). The Wilder Collaboration Factors Inventory asks respondents to indicate their level of agreement with statements about their collaborative group on a 5-point scale (1 = *strongly disagree* to 5 = *strongly agree*). Survey developers created the items in alignment with the research on what makes collaborative endeavors successful. Responses are averaged, and factors rating 4 or above are considered healthy aspects of the partnership that do not need special attention. Factors rated 3.00 to 3.90 are borderline, indicating areas that may need attention. Factors rated below 3.00 are considered in need of attention. In the PLANETS version of the survey, when respondents disagreed with an item, they were prompted to explain their response, as a mechanism of eliciting feedback for improvement. The explanation of the factors included in the Wilder Collaboration Factors Inventory and adapted for use in the PLANETS survey is included in Appendix G. The PLANETS team's responses to the individual items in the survey in Years 1–3 and Year 5[5] are presented in Appendix H.

Building and Strengthening Relationships

Relationship building in a collaborative group includes establishing trust and respect among partners, seeing the benefits of collaborating, and developing a shared vision for the communal work of the project. Findings from Years 1–3 and Year 5 are compared in this section of the report.

MUTUAL RESPECT, UNDERSTANDING, AND TRUST

Trust is essential to the work of collaborative groups (Mattessich et al., 2001; Thomson, Perry, & Miller, 2007). Partners rated this factor highly for the PLANETS partnership in both Years 1–3 and Year 5, with the highest mean rating in Year 3 (Figure 3). Five years of collaborative work has led to a high degree of respect and trust among partners.

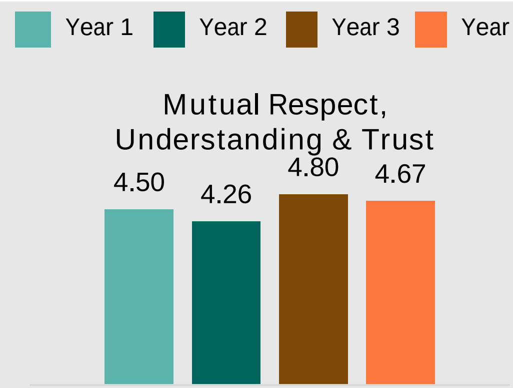

Figure 3. Mean partner ratings on items related to trust and respect among PLANETS partners

COLLABORATION AND SELF-INTEREST

If a partnership is to be successful, it must foster mutually beneficial relationships that benefit the participating individuals as well as their organizations (Cunningham & Tedesco, 2001; Garza, 2005). Across the 5 years of the project, partners saw PLANETS as beneficial to them and to their organizations, with the highest mean rating in Year 5 (Figure 4).

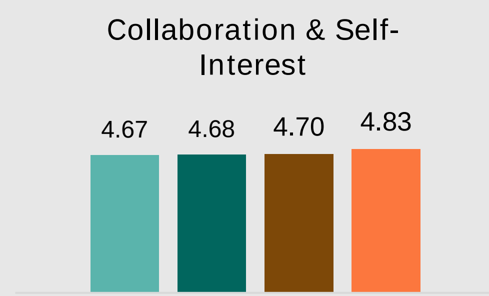

Figure 4. Mean partner ratings on items related to organizational benefits of participating in PLANETS

[5] Evaluators did not use the Wilder Collaboration Factors Inventory in Year 4. Instead, evaluators used the PLANETS Reflection Survey to ask participants to reflect on four questions related to the project and their roles. See Haden & Peery, 2019.

APPROPRIATE CROSS SECTION OF MEMBERS

Successful collaborative projects involve stakeholders who will be impacted by the project's activities. PLANETS partners rated this aspect of the partnership highly in all years of the project, though it declined slightly in Year 5 (Figure 5).

ABILITY TO COMPROMISE

Successful collaborative projects involve the ability of members to compromise so that the greater good of the project can advance (Mattessich et al., 2001). Partners rated the ability to compromise highly, with the highest mean rating in Year 5 (Figure 6).

MEMBERS SHARE STAKE IN PROCESS AND OUTCOMES

Across years, mean ratings for having a shared stake in the PLANETS project process and outcomes indicate that the partnership functioned well in this respect, especially in Year 5 (Figure 7).

MULTIPLE LAYERS OF PARTICIPATION

Having multiple layers of participation requires having the appropriate and necessary staff from each organization support the project, integrating efforts throughout all the members' systems, and ensuring that organizations contribute key people who can help assure the project's success (Mattessich et al., 2001). Across Years 1–3, mean ratings for the two items related to this factor scored below 4.00, indicating a possible area in need of attention. This rating had a mean rating of 4.00 in Year 5 (Figure 8).

FLEXIBILITY

With respect to collaboration, flexibility involves both structure and methods. Mattessich et al. (2001) noted, "Monitoring the collaborative to ensure it remains flexible is important since groups often tend over time to solidify their norms in ways that constrain their thinking and their behavior" (p. 20). In Years 1 and 2, mean ratings for flexibility were just under 4.00. The mean rating rose above the 4.00 threshold of concern in Year 3 and continued to rise in Year 5 (Figure 9).

CLEAR ROLES AND RESPONSIBILITIES

For partnerships to be successful, partners must "clearly understand their roles, rights, and responsibilities and understand how to carry out those responsibilities"

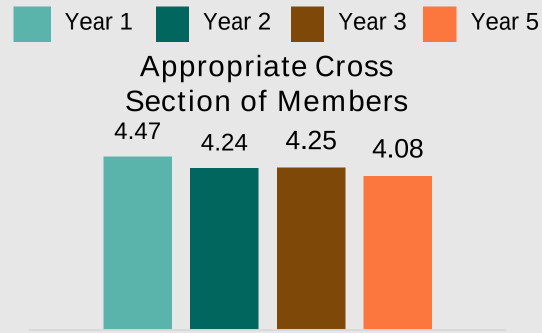

Figure 5. Mean partner ratings on items related to an appropriate cross section of members

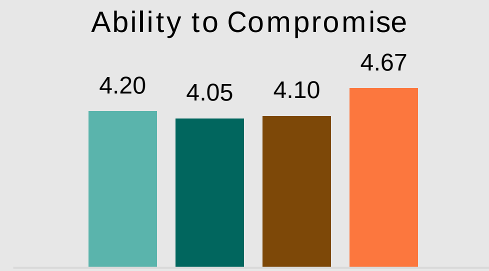

Figure 6. Mean partner ratings on items related to PLANETS partners' ability to compromise

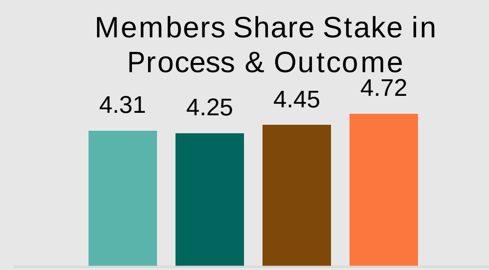

Figure 7. Mean partner ratings on items related to processes and outcomes

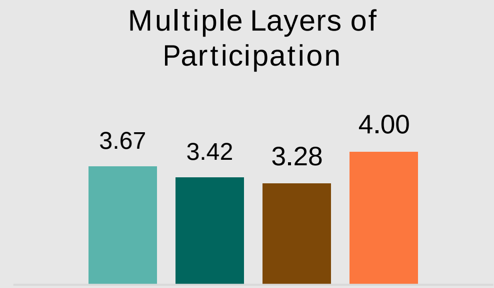

Figure 8. Mean partner ratings on items related to multiple layers of participation

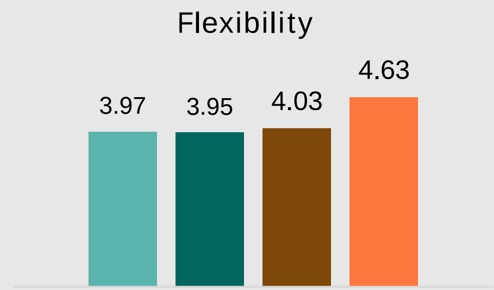

Figure 9. Mean partner ratings on items related to flexibility of members

(Mattessich et al., 2001, p. 20). For Years 1–3 of the project, the mean rating for this factor was below 4.00, indicating an area to monitor. In Year 5, the mean rating rose to 4.00, the threshold of concern (Figure 10).

APPROPRIATE PACE OF DEVELOPMENT

In a successful collaborative project, "the structure, resources, and activities of the collaborative change over time to meet the needs of the group without overwhelming its capacity" (Mattessich et al., 2001, p. 22). Mean ratings for these items were below 4.00 in Years 1–3 of the project. In Year 5, this mean rating rose above the 4.00 threshold of concern (Figure 11).

COMMUNICATION

Open and frequent communication is essential to successful partnerships (Clifford & Millar, 2008; Mattessich et al., 2001). To function optimally, partnerships must have clear information flows between organizations and among partners within the same organization (Organization for Economic Cooperation and Development, 2006). Mean ratings for these items were below 4.00 in Years 1–3 of the project. In Year 5, the mean rating rose above the threshold of concern (Figure 12).

CONCRETE, ATTAINABLE GOALS AND OBJECTIVES

If partners are to accomplish assigned responsibilities, tasks and timelines must be clearly defined and partners must feel that goals are reasonable (Mattessich et al., 2001). Mean ratings for items related to concrete, attainable goals and objectives increased each year of the project (Figure 13).

DEVELOPING A SHARED VISION AND UNIQUE PURPOSE

A primary component of a successful collaborative project is a shared vision for the work (Mattessich et al., 2001). The mean rating for items regarding a shared vision for PLANETS increased each year of the project, indicating that this aspect of the partnership was healthy (Figure 14). Each year, partners also rated highly items related to PLANETS having a unique purpose that defined its "sphere of activity" (Figure 15).

PROVIDING STRONG LEADERSHIP

Effective leadership of a collaborative group requires strong organizational and interpersonal skills (Mattessich et al., 2001). Skilled leaders are an important factor in

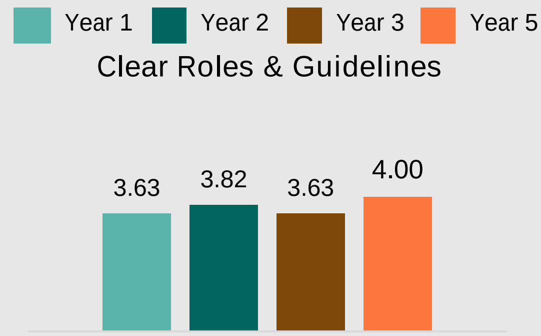

Figure 10. Mean partner ratings on items related to clear roles and responsibilities

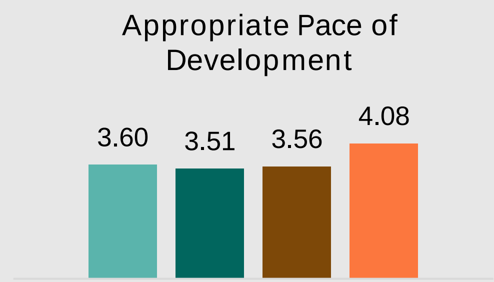

Figure 11. Mean partner ratings on items related to pace of development

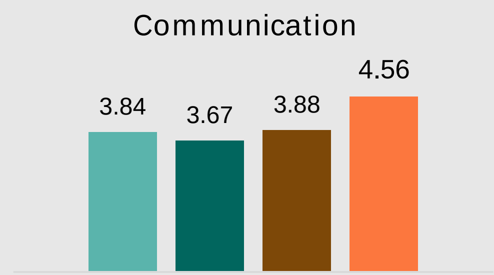

Figure 12. Mean partner ratings on items related to communication

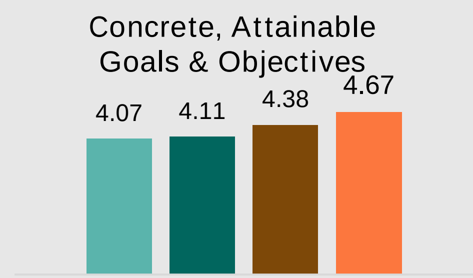

Figure 13. Mean partner ratings on items related to PLANETS goals and objectives

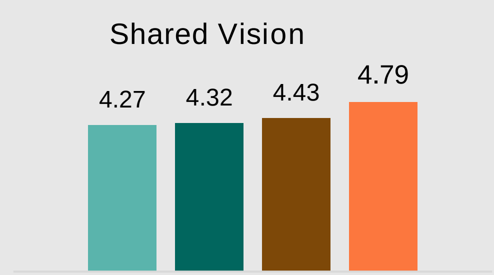

Figure 14. Mean partner ratings on items related to a shared vision

facilitating cooperation among members and moving the work of the collaborative group forward (Organization for Economic Cooperation and Development, 2006). Partners rated PLANETS leadership highly across all years, a factor that they noted contributed to project success (Figure 16).

As shown in the survey results across the 5 years of PLANETS, the partnership functioned well, and relationships and collaborations solidified over the project period, setting the stage for productive collaboration in the next phase of work (PLANETS 2.0). Lessons learned regarding effective collaboration will inform how the group operates in the future.

When reflecting on the work of PLANETS, key partners identified the idea of the collaborative itself as one of its greatest successes. As noted in the survey and in annual interviews, they consistently saw the PLANETS collaborative in their self-interest and felt the group shared a vision for the work. They recognized goals as attainable, and they shared a common view of the partnership as having a unique purpose. The leadership team was viewed as highly skilled. A noted strength was the way the partners fostered an environment that welcomed new members.

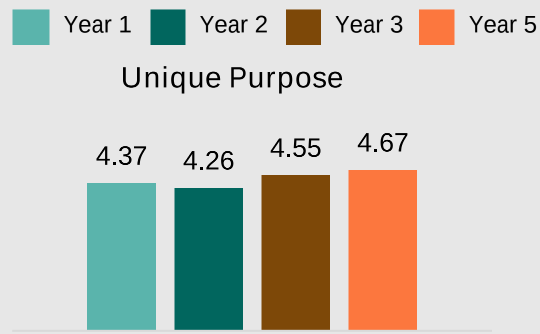

Figure 15. Mean partner ratings on items related to a unique purpose

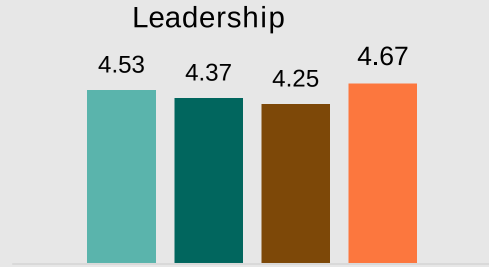

Figure 16. Mean partner ratings on items related to leadership

Partnership Lessons Learned

In interviews, partners identified lessons learned over the course of the project. Though it rated highly and has improved over time, decision making is an area that could continue to improve in the next phase of work, with a clearer process for making decisions. Another identified area for improvement is the participation of an appropriate cross section of members. This is likely due to the recognition that the PLANETS collaborative would benefit from more diversity in its partners to support the goal of broadening participation in STEM, which is the focus of future work in PLANETS 2.0.

> *One of the lessons learned is that we needed, at the beginning, to spell out roles and responsibilities and communication. There's an opportunity to build on knowing that and working on it from the start with new partners [in PLANETS 2.0].*
>
> —PLANETS Partner Interview

In discussing lessons learned to apply to PLANETS 2.0, the team suggested roles, responsibilities, and pacing of development as areas to revisit frequently in the next phase of work. As group members changed, roles and responsibilities needed adjustment, and organizations had varying demands on their time and different ways of working. Partners must remain flexible with their expectations of one another's participation. In interviews, team members also noted the need for a clearer process for onboarding and orienting new members if team members (particularly institutional leads) leave the project. Finally, moving forward, communication across organizations was identified as an area to monitor and improve through more frequent sharing among project teams. Additionally, one team member noted the need to "concisely and quickly select tangible products and tasks needed for the work as determined in the scope." This individual noted that, at times, the team "drifted back and forth on what they really wanted to produce" and that laying out clear guidelines from the start would have improved the collaboration.

Impacts of the Interdisciplinary Partnership

> ? What were the impacts of the partnership on project partners and their institutions?

To understand impacts of participation in the project on individual partners and their institutions, the evaluation used annual survey data (including annual PWG surveys and reflection surveys) and in-depth interviews. When responding to questions about how participating in PLANETS impacted their organizations, partners commented on the recognition imparted to their organizations by being part of a project funded by NASA, a respected national agency. Partners commented that their organizations "gained more national recognition and visibility," and that participating gave their organizations "clout and validation" as NASA grantees and partners.

Key Partner Impacts

- ✓ Working on a national-level, NASA-funded project increased organizational visibility.
- ✓ Learning from others outside of partners' areas of expertise increased individual and organizational learning.

> *Being a contributing member to a large-scale NASA educational product has been important to all of our organizations.*
>
> —PLANETS Partner Interview

Partners felt that the cross-organizational partnerships within the PLANETS project provided new ways to collaborate and provided new insights into education work. For example, one commented that the "level of collaboration" with PLANETS partners was a new way of working for their organization and "established a foundation around which we could base future collaborations."

Team members also noted the benefits of tapping into each other's networks in science education. An MOS partner commented, "Within science and engineering education, the NASA connections and the science connections brought resources to us. This allowed us to get into spaces and places we wouldn't be able to otherwise access in our curricular products."

Partners also felt that PLANETS, in turn, contributed meaningfully to NASA's educational goals. As one partner noted,

> *We are part of this consortium of projects. And with us and the other teams of the consortium, we are a grand five-year experiment in how to change and update NASA's education—not just techniques but their goals for education. We have significantly contributed to those goals and the future of those.*

PLANETS partners also noted that they benefited personally and professionally by being part of the project. Across the years, SMEs learned about curriculum development and effective teaching practices; educators learned science and engineering content from SMEs; and SMEs and MOS partners learned about effective educator resources. This collaboration across disciplines was one of the things partners consistently noted as a strength of PLANETS. A typical partner comment was:

> *The SMEs have ideas that the educators don't think of because they just don't have the [content] background, and the educators know how to turn those into something useful for education rather than just throwing facts at people.*
>
> —PLANETS Partner Interview

> *It's that collaboration between the institutions working together and drawing upon each group's expertise. We couldn't do it alone. Our strength is that we recognize that not one group has all of the knowledge and skills to complete this project alone. So, our strength is that collaboration.*

Objective 2: Develop Nationally Available Curricular Units to Reach Underserved Populations

The PLANETS project aimed to develop curricular units and novel ancillary materials appropriate for OST contexts by integrating new and existing NASA assets, planetary science content, and engineering processes and habits of mind. PLANETS research on curriculum implementation focused on student attitudes toward engineering, particularly among youth from populations that are underrepresented in STEM fields.

The following section describes the development of the curricular units after 5 years of the project and then examines how well the project reached its target audience and impacted participating youth's abilities to engage in targeted engineering habits of mind and attitudes toward science and engineering.

Development of the PLANETS Units

PLANETS partner MOS took the primary role in developing the PLANETS engineering curriculum. The USGS planetary scientists served as SMEs for the curriculum development process and also worked with CSTL to develop Science Series guides that complement the engineering activities and content in the units.

PLANETS units consist of three components: an engineering guide, a Science Series science guide, and educator resources. Developed by MOS, the PLANETS Engineering is Everywhere (EiE) guides engage youth in the engineering design process around NASA-inspired space science themes. The PLANETS Science Series guides include activities and games to enhance understanding of the science that supports the engineering content in the units (Figure 17). Educator resources are accessed via https://planets-stem.org/. Resources include downloadable engineering and science guides, how-to videos, content videos, quick tips, key vocabulary, links to NASA resources and live mission updates, and teaching tips, among other things.

Figure 17. PLANETS engineering and science guides

Table 2 shows the units, components, grade level, and focus.

Table 2. PLANETS unit descriptions

	Remote Sensing	*Water in Extreme Environments*	*Space Hazards*
Grade Level	6–8	6–8	3–5
Engineering Guide	*Worlds Apart: Engineering Remote Sensing Devices*	*Testing the Waters: Engineering a Water Reuse Process*	*In Good Hands: Engineering Space Gloves*
Science Guide	*Remote Sensing of Mars*	*Water in the Solar System*	*Space Hazards*
Focus	A unit to understand how scientists and engineers use remote sensing technologies to study remote worlds	A unit to understand how scientists and engineers design systems for reusing water and how we can study water on remote worlds	A unit to understand how scientists and engineers design materials to mitigate hazards on Earth and in space

Lunar Landform Mystery

Year 4 of the project occurred during the 50th anniversary of the Apollo 11 moon landing. NAU and USGS engaged in a new partnership with Lowell Observatory in Flagstaff, AZ, to create a supplemental PLANETS curricular guide in conjunction with the anniversary celebrations. In *Lunar Landform Mystery*, youth in grades 4–5 explore evidence of geological processes on both the Earth and the Moon that could have resulted in the formation of a mystery landform feature on the surface of the Moon. This guide was not originally a part of the PLANETS plan, but it leveraged a community partner and a historic celebration.

NASA SMD Independent Product Review

The PLANETS team submitted the completed middle school guides for review by NASA's SMD product review panel. The intent of independent product review is to ensure that educational products distributed by NASA are of high quality. Products that pass the review are identified as exemplary products and listed in the NASA Wavelength database at http://nasawavelength.org. The *Testing the Waters* and *Worlds Apart* engineering guides both passed the independent review with ratings of *very good* to *outstanding*. The PLANETS team submitted the *In Good Hands* upper elementary engineering guide for independent product review in December 2020.

Incorporation of NASA Assets into Curriculum Development

A goal of the SciAct program is the use of NASA assets to foster engagement with and awareness of NASA missions, programs, and products. PLANETS incorporated NASA assets in the development of the three units. These included special report videos, NASA images, topographic maps of Mars, artists' renderings of space, "Did you know?" facts, infrared light images, links to NASA mission pages, and NASA data. Links to NASA career videos, including women in STEM, were also included in the educator resources. Additionally, NASA-funded scientific and technical personnel were included in special report video interviews for the units. A list of NASA assets and their incorporation into the *Remote Sensing* unit is presented in Appendix I as an example of asset integration. A list of NASA assets for the *Water in Extreme Environments* and *Space Hazards* units is available upon request.

Implementation of the PLANETS Materials

During the field test, educators used the *Remote Sensing* and *Water in Extreme Environments* units with youth in their OST programs. Thirteen of these educators completed the implementation logs as part of the field test. Based on the log results, these educators typically used the following materials or resources to teach STEM in their OST time program before PLANETS: teacher-created labs and materials (85%), science education websites (69%), video clips/internet streamed videos (54%), science textbook and materials (46%), and Foss Kits (15%). Thirty-one percent of educators indicated other, noting they used kids, Lego curriculum, Teacher pay Teacher and toys and games.

Additionally, results from these logs show that educators spent an average of 34.17 minutes (SD = 19.40, Mdn = 30.00) planning and preparing for the engineering materials and 33.50 minutes (SD = 24.61, Mdn = 35.00) planning and preparing for the science materials.[6] The educators for *Remote Sensing* and *Water in Extreme Environments* used the materials for an average of 1.45 and 2.25 days per week and 1.65 and 0.96 hours per week, respectively. Educators for *Remote Sensing*[7] and *Water in Extreme Environments* indicated that they spent

[6] One educator did not provide this information, and two educators did not use the science materials during the field test.
[7] Includes the eight educators who completed all weekly logs for the *Remote Sensing* field test.

an average of approximately 17.31 and 11.00 total hours, respectively, implementing the curriculum with their youth.

On average, 11 educators used all the engineering and science activities. Two educators did not complete any of the science activities. One of these educators explained that the science activities were planned for the following semester. One educator did not complete the final activity—the Engineering Showcase—because COVID-19 required the OST program to return to remote learning and the showcase day was cancelled. Additionally, four educators described major changes they made to the engineering guides' activities and materials. The major changes to the *Remote Sensing* unit included moving on earlier than planned due to youth losing interest, and using additional websites since they did not have the materials and correct website links at the start of the unit. The major changes to the *Water in Extreme Environments* unit included adding a virtual tour of a wastewater treatment plant to show youth how water is reused at a bigger scale and covering the first two activities regarding technology in the first day. No educators shared any major changes that they made to the science guides' activities and materials. All educators indicated that they used the engineering notebook with their youth.

Quality and Utility of the Materials

The educators provided important feedback about the quality and utility of these materials in implementation logs. On a scale ranging from 1 (*very difficult*) to 5 (*very easy*), 13 educators indicated that it was easy (M = 4.00, SD = .82), on average, to adapt the materials to their teaching setting. Educators also rated their agreement with statements about the quality of the materials on a 5-point scale, from 1 (*strongly disagree)* to 5 (*strongly agree*) (Figure 18).

Figure 18. Educator average ratings of the quality of the materials (*n* = 13)

As shown in Figure 18, educators rated their agreement the highest, on average, with the following statements: "Overall, the materials are very useful" (*M* = 4.15, *SD* = 1.07) and "The background information was useful to understanding how to use the materials" (*M* = 4.15, *SD* = 1.14). Educators, on average, showed the lowest agreement with this statement: "The activities were developmentally appropriate for my learners" (*M* = 3.62, *SD* = 1.26). See Appendix J for the quality ratings disaggregated by unit.

Educators also shared which barriers hindered their ability to make better use of these materials in their instruction. Results showed that 31% of the educators had no barriers. The nine educators who indicated there were barriers shared the following ones: limited class time available (33%), not appropriate for grade level (22%), lack of sufficient planning time (22%), and no access to necessary materials and resources (11%). Two *Water in Extreme Environments* educators indicated that inconsistent student attendance was a barrier.[8] Two educators indicated other barriers, including that the materials were not relatable to the youth, or lessons took longer than the anticipated time.

[8] This barrier was only an option on the *Water in Extreme Environments* implementation log.

Additionally, 62% of these educators indicated that the inclusion of the Next Generation Science Standards in the guide front matter was useful to their instruction in an OST environment, 31% indicated it was somewhat useful, and 8% indicated it was not useful. Eighty-five percent of these educators indicated that they plan to use the curriculum again, and 15% indicated that they may use the curriculum again.

PLANETS Reach and Impact

As part of the summative evaluation, external evaluators examined the following three summative evaluation questions:

- Did the program reach the target audience for the materials developed?
- Did youth show more positive attitudes toward science and engineering as a result of participating?
- Did youth show the ability to engage in targeted engineering habits of mind as a result of participating?

To address these questions, evaluators used data from the field tests conducted in diverse OST programs during fall 2019 and fall 2020. Data collection methods included educator implementation logs, educator interviews, observations at two of the OST sites, and a youth Engineering Interest and Attitudes survey.

Reaching the Target Audience

? Did the program reach the target audience for the materials developed?

The participating 11 OST field test sites were very diverse, with a high percentage, on average, of minority students (73%) and economically disadvantaged learners (73%). There were slightly more boys (55%), on average, than girls (45%).[9]

The final analysis sample included 163 youth, 51% of whom were boys, 44% were girls, and 4% identified as other (e.g., nonbinary or both). Additionally, 31% were White, 30% were Black or African American, 28% were Hispanic, 4% were Asian, and 7% were Multiracial or Other.

Target Audience

✓ The OST sites were very diverse, with high percentages of minority and economically disadvantaged youth.

Youth Interest and Attitudes

? Did youth show more positive attitudes toward science and engineering as a result of participating?

[9] This is based on study applications for the OST sites. One site's data is from EIA demographic data because the site did not provide clear information on the application.

Youth who participated in the field test of the two engineering guides developed by MOS completed the Engineering Interest and Attitudes Survey (EIA) (Cunningham & Lachapelle, 2010). The retrospective survey contains 19 items where youth rate their level of agreement with items related to their engineering interest and attitudes prior to and after participating in the engineering activities. The EIA has five subscales: Aspirations, Enjoyment, School, Value to Me, and Value to Society. Items for each scale are totaled.[10]

Youth Interest & Attitudes

- ✓ Youth interest and attitudes toward science and engineering significantly increased as a result of participating in PLANETS.
- ✓ OST educators' perceptions of students' learning and engagement with the materials leaned toward the positive.

Figure 19 shows the findings of EIA data from the two field tests, disaggregated by subscale. The final sample size for these analyses was 163 youth. Youth were not included in the analyses if they were missing substantial or all pretest and/or posttest data (*n* = 14), attended less than 80% of the engineering curriculum (*n* = 26), did not give consent (*n* = 1), or did not meet sample criteria (*n* = 7). Evaluators conducted paired samples *t*-tests on the EIA data, and results showed that interest and attitudes significantly increased across all subscales. Appendix K presents the statistical analyses for these findings and disaggregated by units.

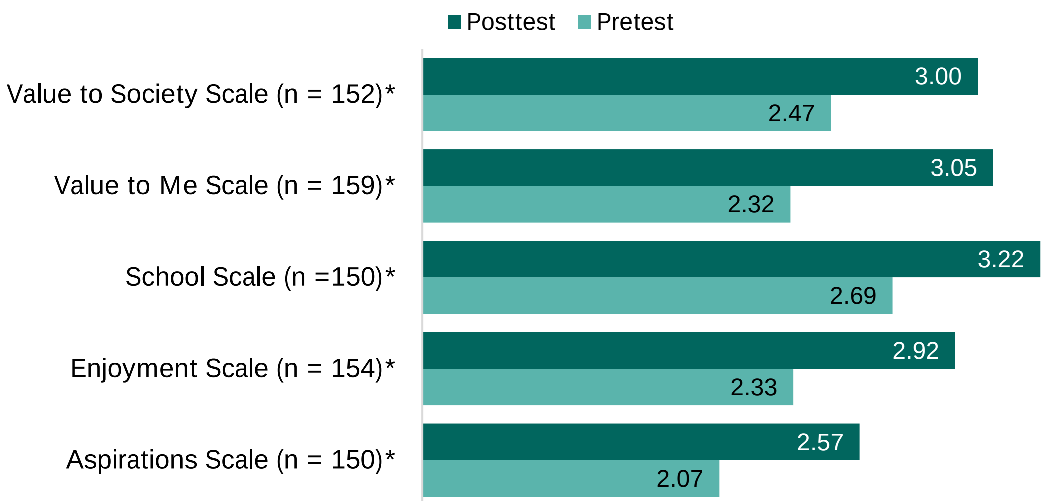

Figure 19. EIA *Worlds Apart* and *Testing the Waters* scale means, combined
*Statistically significant

In addition to the EIA surveys, educators shared the extent to which they agreed with statements about their students' engagement and learning on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Educators' average ratings of their students' learning and engagement ranged from *neither agree nor disagree* to *agree* in all areas (Figure 20).

[10] Subscales did not have the same number of items; thus, the possible range for each subscale varies.

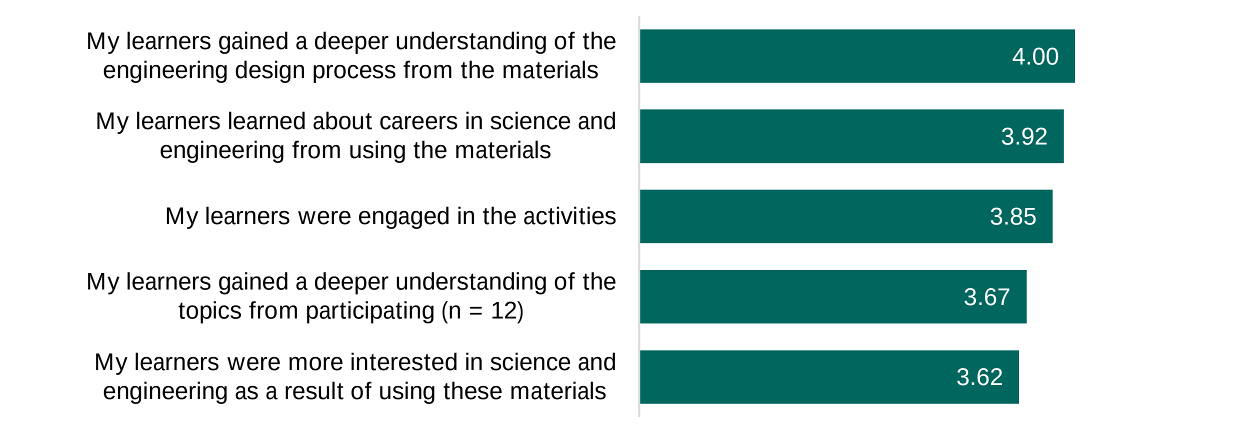

Figure 20. Educator average ratings of their students' learning and engagement (*n* = 13)

Interviews with field test educators revealed common themes related to interest in science and engineering. Educators consistently commented that youth were most engaged when designing and building and when solving problems. Youth were less engaged when they had to write answers to questions. Educators noted for both units that the engineering guides seemed to be more engaging for their students than the science guides because of the active nature of the engineering design cycle. A *Remote Sensing* educator commented, "They were less engaged in the *Remote Sensing on Mars* activities because it was not as hands-on; they weren't creating things." Another noted that the engineering lessons "grabbed the kids' attention right away" but that the science guides were less engaging.

> *Any time they had a chance to build or to think freely. Anytime they are given a free choice, they get very excited and very engaged.*
> —PLANETS Field Test Educator

Engineering Habits of Mind

? Did youth show the ability to engage in targeted engineering habits of mind as a result of participating?

PLANETS team members from CSTL and MOS began a research study in January 2018 that examined how participating in the PLANETS middle school engineering activities affected youth interest, attitudes, agency, and engineering habits of mind, and educator capacity to support STEM in OST contexts. The study took place in four middle school OST settings: two in Arizona (including one site on the Navajo Nation) and two in Massachusetts. Four educators and 52 youth participated in the studies. Researchers assigned sites to use one of the two

Engineering Habits of Mind

Youth in research and field test sites:

- ✓ Collaborated and negotiated to address an engineering challenge
- ✓ Persisted through failure to achieve successful designs
- ✓ Celebrated success earned through repeated testing and retesting of designs

PLANETS middle school engineering guides, *Testing the Waters: Engineering a Water Reuse Process* or *Worlds Apart: Engineering Remote Sensing Devices*. The guides were designed for youth to work collaboratively to respond to a problem, using the engineering design process. Researchers reviewed and coded video and audio recordings of youth participating in the activities, and also collected youth surveys, youth focus group data, and engineering journals. Researchers examined the videos and identified instances where youth appeared to be employing practices or engineering habits of mind. Qualitative coding of video revealed three habits of mind that enhance student attitudes toward engineering (San Antonio-Tunis, Clark & Cunningham, 2019: Bloom & Clark, 2017):

- Negotiating designs collaboratively: working together to design a solution to the given engineering challenge
- Persisting through failure: evaluating what went wrong in a design, and planning for improvement
- Celebrating success: celebrating when a design improvement results in a positive outcome

Interviews with educators who used the two middle school units with their youth corroborated the research team's findings. Educators noted that students who wanted to work alone, or others who wanted to "be in control" of the group, came to value the benefits of working collaboratively, as engineers do in real life. One commented,

> *Some groups, in the beginning, will have one student that just wants to control [everything], one student that wants to do nothing, and one student that is just going with the flow. By the time we were getting close to the engineering showcase (at the end of the unit), everyone was participating, everyone was talking to each other, and they were giving each other critical feedback, which was good.*

Educators also noted that youth persisted through failure after initially being discouraged when their designs failed. For example, an educator using *Remote Sensing* commented,

> *Once they started to fail the first time, they wanted to stop, and then afterwards they started to persist a little bit more, and they started to focus more on what their project needed to make their periscope look better or their LIDAR detection tool work better. So, it really started with them wanting it to be solved—and then they started to persist.*

Interestingly, two educators (one using *Water in Extreme Environments*, the other using *Remote Sensing*) commented that their lower-achieving or special education students fared well with the engineering design cycle because they were used to struggling to get answers. They didn't expect to "get it right" the first time.

> *One student wanted to do it alone. In the real world, people don't work alone. You have to plan and strategize and work together. This student reluctantly worked with a partner, and then became the leader of the group. [The students learn] they need to bounce ideas off of each other and brainstorm together.*
>
> —PLANETS Educator

COVID-19 Implications for Curriculum Development

With the onset of the COVID-19 pandemic in March 2020, several of the PLANETS project and evaluation activities were interrupted. Some project activities were cancelled, other activities were postponed, and new activities were undertaken in response. Professional development workshops scheduled for the National AfterSchool Association's annual conference were cancelled, and other workshops planned for summer 2020 were put on hold. Pilot, field test, and research cycles were also disrupted. However, the PLANETS team did find new opportunities for adapting and disseminating PLANETS products in response to the disruptions.

PLANETS@Home as a Response to COVID-19

In response to museum closures, the MOS staff conducted surveys of parents and educators to understand how the museum could respond to stakeholder needs in the time of COVID-19. Key findings from the surveys are presented in the PLANETS annual progress report to NASA (Clark, 2020a). The PLANETS team used the survey findings to respond to educator, youth, and family needs, including the need for:

- High-quality STEM engagement
- Activities that are self-directed, are hands-on, use at-home materials, fall in the 30- to 40-minute time range, and use a variety of modalities
- Resources and activities that are cognizant of technology accessibility and the time/resources of families

Guided by stakeholder needs, the PLANETS teams co-created a series of new science and engineering activities using content from each of the three PLANETS units. The PLANETS@Home activities were designed as games and investigations for youth to complete at home with little direction needed from adult family members. Each game or investigation was estimated to take youth 30–40 minutes to complete.

PLANETS@Home

✓ 605 PLANETS STEM bags distributed to community partners

Website kits ordered:

✓ 90 *Space Hazards* Game

✓ 83 *Water in Extreme Environments* Game

✓ 76 *Remote Sensing* Investigation

The PLANETS team used community contacts in northern Arizona and the PLANETS website to disseminate the PLANETS@Home activities. Kits containing the PLANETS@Home activities were distributed to the Boys & Girls Club of Flagstaff (150 bags), the Flagstaff Family Food Center (20 bags), the Flagstaff Festival of Science (300 bags), and Second Mesa Day School (135 bags), which is located on the Hopi reservation. These organizations then distributed the kits to families utilizing their services.

PLANETS@Home activities were also advertised on social media throughout July and August 2020. Posts included links to an "Apply for the Kit" order form on the PLANETS website (planets-stem.org/planets-at-home/), which made the STEM kits available to families and educators at no cost. Website orders through December 2020 included 249 PLANETS@Home kits sent to families across the nation and internationally.

Game and investigation instructions and printable materials for all activities are also available for download on the website at no cost. Activities were designed so that a variety of common materials could be used and access to specific resources and technology was not required. As of December 2020, there had been 121 downloads of the PLANETS@Home activities.

As of December 2020, a total of 854 STEM bags had been delivered to families. Of the kits distributed to community partners, more than half (57%) of the youth reached were underserved, as reported via the website or by a school organization or as estimated from the demographics of youth enrolled in Flagstaff Unified School District. Additional demographic information was collected from the website applications, of which 34% reported low-income status and 19% reported having at least one player with a disability.

Social Media Outreach

Concurrent with the PLANETS@Home STEM kit distribution and the PLANETS@Home activities made available on the website, USGS partners launched a social media campaign to raise awareness of these resources. This included posts to Instagram, Facebook, and Twitter from the USGS Astrogeology account in order to leverage an existing audience of followers. Posts featured images and videos of the created games and investigations as well as seven "Ask a Scientist" videos of SMEs answering questions (Clark, 2020a). Questions were informed by the PLANETS activities or current NASA news and announcements, or were gathered from an "Ask a Scientist" form on the PLANETS@Home website (planets-stem.org/planets-at-home/). As of December 2020, the 18 posted videos had had a collective 11,905 views on social media. These videos are also included on the PLANETS@Home website with the "Ask a Scientist" form. The USGS PLANETS social media campaign had the following total reach[11]: Facebook (19,436), Instagram (14,986), and Twitter (12,144), with a total of 46,566 across the three accounts. Following of the accounts also increased over the course of the campaign, as depicted in Figure 21.

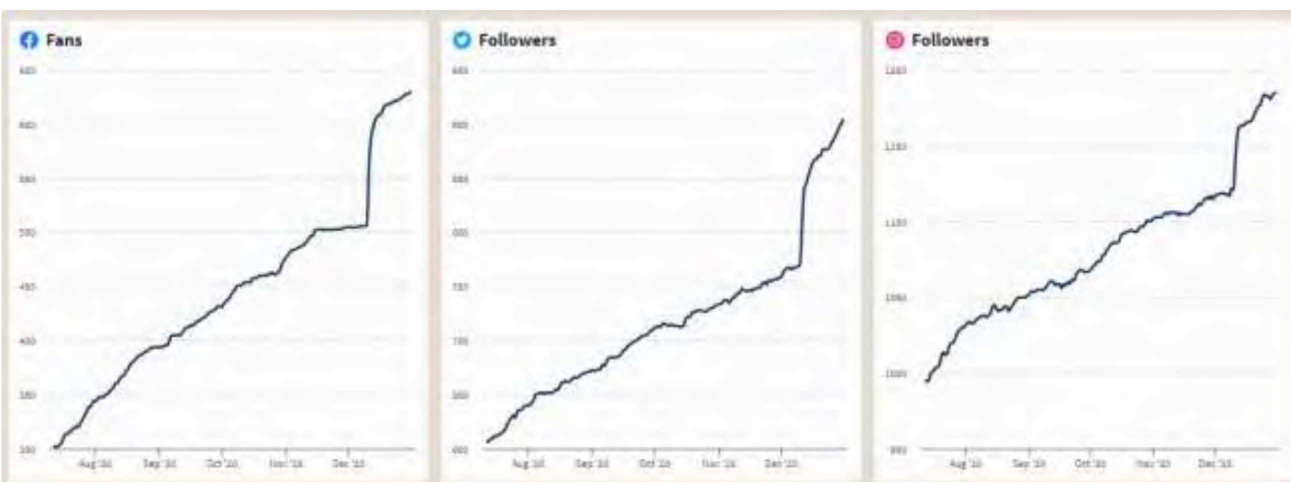

Figure 21. Followers on USGS Facebook, Twitter, and Instagram

[11] These numbers represent the total reach of USGS posts which includes video views over 30 seconds, likes/reacts, and comments.

Partner Perceptions of PLANETS Response to COVID-19

In final PLANETS 1.0 partner interviews, partners discussed the impact of COVID-19 on the PLANETS project. As previously noted, piloting and field testing of the PLANETS units were postponed due to OST program closures. Partners commented that the cohesiveness of the project team after nearly 5 years of working together allowed team members to pivot and work collaboratively to respond to new and emerging needs of educators, families, and youth. A typical partner response was, "The COVID response team started their work early on. Which again is a testament to the ability of the group to pull from different funds of knowledge, and be able to support each other and the project, and the ability to collaborate, especially over a distance."

> *[COVID-19] forced everyone into virtual delivery. So, the idea of providing short, at-home activities to engage families through the Boys and Girls Club, and the STEM bags wouldn't have happened if we didn't realize that parents were scrambling for ideas to engage their kids when there were no camps or school. I think it inspired innovation.*
>
> —PLANETS Partner Interview

One partner commented that PLANETS@Home made the team think about the needs of families who might not have access to all of the things needed to do the activities in a program setting. For example, one partner said,

> *For the COVID pivot, in everything that we created, we considered the most disadvantaged people we could think of in the writing of the unit. For instance, we did not use clean water for the engineering activity, because it is hard to come by on a reservation. We had a lot of lengthy discussions about how to design these products for underserved populations.*

With respect to challenges the team experienced with PLANETS@Home, team members noted that it was difficult to get feedback from users of the STEM kits. Each kit came with a stamped postcard with a few short survey items about how participants like the activities, and none were returned. They also struggled with the best way to promote the materials, especially for those who do not use social media.

Objective 3: Create and Test Educator Resources

The PLANETS project aimed to create educator resources for self-directed learning to support OST educators in implementing program materials effectively, and to collect evidence of resource use by educators through research and field testing of the units.

The following section describes the creation of the educator resources in the 5 years of the project and then examines the impact of the educator resources on OST providers.

Development of the Educator Resources

CSTL had the primary responsibility for developing educator resources to support the PLANETS units. Educator resources include content knowledge support for the concepts in the units as well as support for the pedagogy and engineering habits of mind inherent in the curricula. See Appendix E for year-by-year progress on Objective 3.

As a first step in educator resource planning, the NAU team conducted a needs assessment of OST providers in Year 1 of PLANETS. During Year 2, the NAU team began planning educator resources, and strategies aligned to the unit curriculum and guides.

In Years 3 and 4 (2018 and 2019), the team designed and conducted educator resource development workshops with OST educators to engage them in co-creating support materials for the three PLANETS units. Workshops were held in Phoenix and Boston in 2018 and in Phoenix and at the annual AGU conference in San Francisco in 2019. Across the workshops, 48 educators participated in reviewing and annotating the educator guides as they read through them, recording their thoughts on how they would implement the activities, what support they would need for implementation, and what support they needed for understanding the content. Through these workshops, the PLANETS team had the involvement of stakeholders in determining what would be most useful to educators in implementing the PLANETS units. See the Years 3 and 4 interim evaluation reports for more detail about the educator resource co-creation workshops (Haden & Peery, 2019, 2020).

Educator Resource Development Feedback

- ✓ Educators gained insights into implementing the lessons effectively.
- ✓ Educators valued collaborating with and learning from educators outside of their networks.
- ✓ Educators felt the workshops were an effective way to co-create useful and usable educator resources.

Field Testing of the PLANETS Units and COVID-19 Adjustments

As part of the summative evaluation of PLANETS, evaluators planned field tests of each unit with educators and youth across the U.S. Prior to discussing field test results, it is necessary to discuss how the COVID-19 pandemic impacted the studies. For each field test, the plan was to include 10–15 educators and their youth in OST programs. The final educator sample across all three field tests was to be 30–45 educators and approximately 500 youth. A full sample was recruited for the *Remote Sensing* field test in fall 2019. However, COVID-19 closures impacted the timing of pilot and field tests of two of the units, *Water in Extreme Environments* and *Space Hazards*.

Water in Extreme Environments Field Test

In spring 2020, evaluators recruited 10 educators for the field study of *Water in Extreme Environments*, the second of three field tests. Educators participated in an orientation to the field test, gave informed consent, and received materials for implementing the *Water in Extreme Environments* unit with their youth. Shortly after receiving materials in March, all of the recruited programs shut down due to COVID-19, and the field study was postponed. In October 2020, three educators resumed the use of the materials and one new educator joined the field test, for a total of four educators who completed the field test activities. Eighty-five youth participated in the field test, of whom 58% were minority students and 68% were economically disadvantaged students, on average across the sites.

Space Hazards Pilot and Field Test

The NAU and MOS teams conducted pilot tests of each unit prior to finalization and subsequent field testing by evaluators. Pilot testing of the Space Hazards engineering guide (*In Good Hands*) by the MOS team was completed in 2019. However, the pilot study of the science guide was suspended in 2020 due to COVID-19, which also postponed the subsequent field testing of the *Space Hazards* unit. The NAU team made the decision to not pilot the *Space Hazards* science guide. Evaluators are currently collecting field test data on the *Space Hazards* unit, including the unpiloted science guide. As of the writing of this report, four sites are participating in the *Space Hazards* field test. Evaluators will update the Year 5 summative evaluation report in May 2021 to include the field test results for the *Space Hazards* unit.

Due to the impacts of COVID-19, overall educator and youth sample sizes were smaller than planned. Evaluators present sample sizes for each data collection method, and readers should interpret findings with caution where sample sizes are small, particularly for educator findings.

Use of Educator Resources in the PLANETS Field Tests

For the *Remote Sensing* and *Water in Extreme Environments* field tests, evaluators asked educators to participate in approximately 3 hours of online professional development by accessing the educator resources at https://planets-stem.org to learn about the content, materials, and resources for the PLANETS units. Resources on the website included how-to videos, content videos, links to NASA videos and resources, teaching tips, and links to professional development opportunities.

After implementing the units, educators completed an implementation log to document how they accessed and used the website resources. Implementation log data showed that 85% of educators who responded to the survey accessed the website for resources to plan or implement the unit. These educators indicated that they spent anywhere from 1 to 20 hours reviewing or using the online educator resources, for an average of 6.00 hours (*SD* = 7.11, *Mdn* = 3.00). Results showed that for almost all the educator resources, at least a few educators (typically 50% or less) indicated that they used them. There were some exceptions, such as the videos, where 50% or more of the educators tended to use them (see Appendix J for a breakdown of the PLANETS website resources and educator access of those resources).

When providing feedback on the website and educator resources during interviews, educators noted that the videos were most useful to their instruction. Educator interviews corroborated these findings, and educators indicated in the interviews that the how-to, content, and NASA videos were most valuable to their instruction.

Impact of Educator Resource Use

As part of the summative evaluation, external evaluators assessed if OST providers who used the educator resources increased their knowledge and skills related to the unit pedagogies and content. This data includes the educator knowledge and skills survey, the implementation log, and in-depth interviews. The 13 educators who completed the implementation log indicated an average of 9.54 years (*SD* = 9.81) of teaching in an OST program and 4.15 years (*SD* = 3.24) of teaching in their current OST program. Appendix L presents educator survey results for content and pedagogy by unit for *Remote Sensing* and *Water in Extreme Environments*. Evaluators will update this section of the report when the *Space Hazards* field test concludes this May.

Support for Instruction

Using a 5-point scale (1 = *to no extent* to 5 = *to a great extent*), educators also shared the extent to which the educator resources supported their instruction (Figure 22). Results show that, on average, the educator resources helped educators prepare and teach the lessons between *to some extent* and *to a good extent*.

Figure 22. Educators' average rating of the extent to which the educator resources supported their instruction (*n* = 13)

Thirty-one percent of these educators used other space science or NASA education materials in their OST program, including AstroCamp, NASA's lessons on gravity, planetary movement, and planetary relationships; NASA Moon landing engineering; NASA impact craters; NASA's BEST; and NASA's Museum in a Box curriculum.

Using a 5-point scale (1 = *strongly disagree* to 5 = *strongly agree*), educators also shared the extent to which they agreed with statements about the effects of the units on their instruction (Figure 23). Educators agreed with nearly all items, on average; most notably, they agreed they would recommend the materials to a colleague (*M* = 4.31, *SD* = 1.11) and would use the materials again (*M* = 4.31, *SD* = 1.1

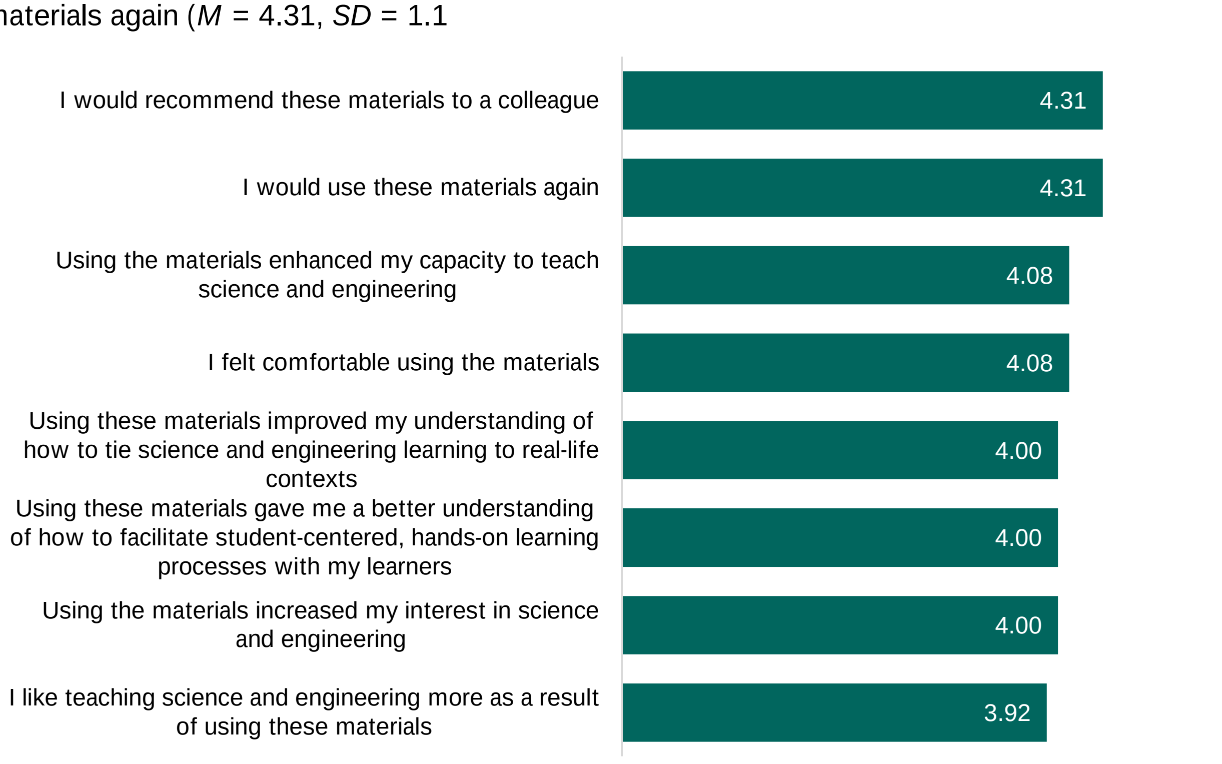

Figure 23. Educator average ratings of the effects of the units on their instruction (*n* = 13)

Educator Knowledge and Skills

Did OST providers who used the educator resources increase their knowledge and skills related to the unit content and pedagogies?

> **Educator Knowledge and Skills**
>
> Educators perceived growth:
>
> - ✓ In their STEM teaching skills as a result of teaching the PLANETS unit
> - ✓ In their content knowledge in most areas as a result of teaching the PLANETS unit, but the growth was greatest for *Remote Sensing*

Eight of the 11 educators who participated in the fall 2019 field test and all four educators in the fall 2020 field test completed a knowledge and skills survey after using the curriculum. The educator knowledge and skills survey included items related to their new teaching skills and their content knowledge before and as a result of teaching their PLANETS unit. Educators perceived growth in all items related to their STEM teaching skills and almost all items related to their content knowledge as a result of teaching the PLANETS unit (Figure 24–Figure 27). The greatest growth occurred for items related to *Remote Sensing* content knowledge. Educators who used the *Water in Extreme Environments* unit reported more growth for their content knowedge about water in the solar system than their content knowledge about water on Earth and tools for measuring and assessing water quality.

When asked in interviews how teaching the units affected their knowledge of the content and their pedagogical strategies, educators' responses varied. Some educators had used MOS EiE units in the past and were familiar with the engineering design process, while others found it a new experience and a new way of teaching in the OST setting. Educators noted that the curriculum reinforced the need for active learning, which involves problem solving and struggling for answers. A seasoned STEM educator commented,

> *While it didn't exactly affect the way I teach, it reminds me to not answer questions for the kids. I had a student group come in yesterday and I asked questions and their teacher answered the questions, rather than letting the kids answer. The importance that science is so much more than just vocabulary…Yes, it's nice now that they know the word "contaminant," but that's not the objective. I liked how balanced it was between vocabulary and experiential learning and the importance of that in STEM in general was reinforced through this.*

Evaluators noted, in interviews and in the two pre-COVID observations they were able to conduct, that educators varied greatly in their background with respect to science and engineering content knowledge and effective pedagogical practices. It was evident in interviews of educators with less extensive educational background and experience that they struggled at times to help their students make sense of the lessons. This speaks to the need to ensure that support materials are accessible for OST educators regardless of the level of their content knowledge in science and engineering.

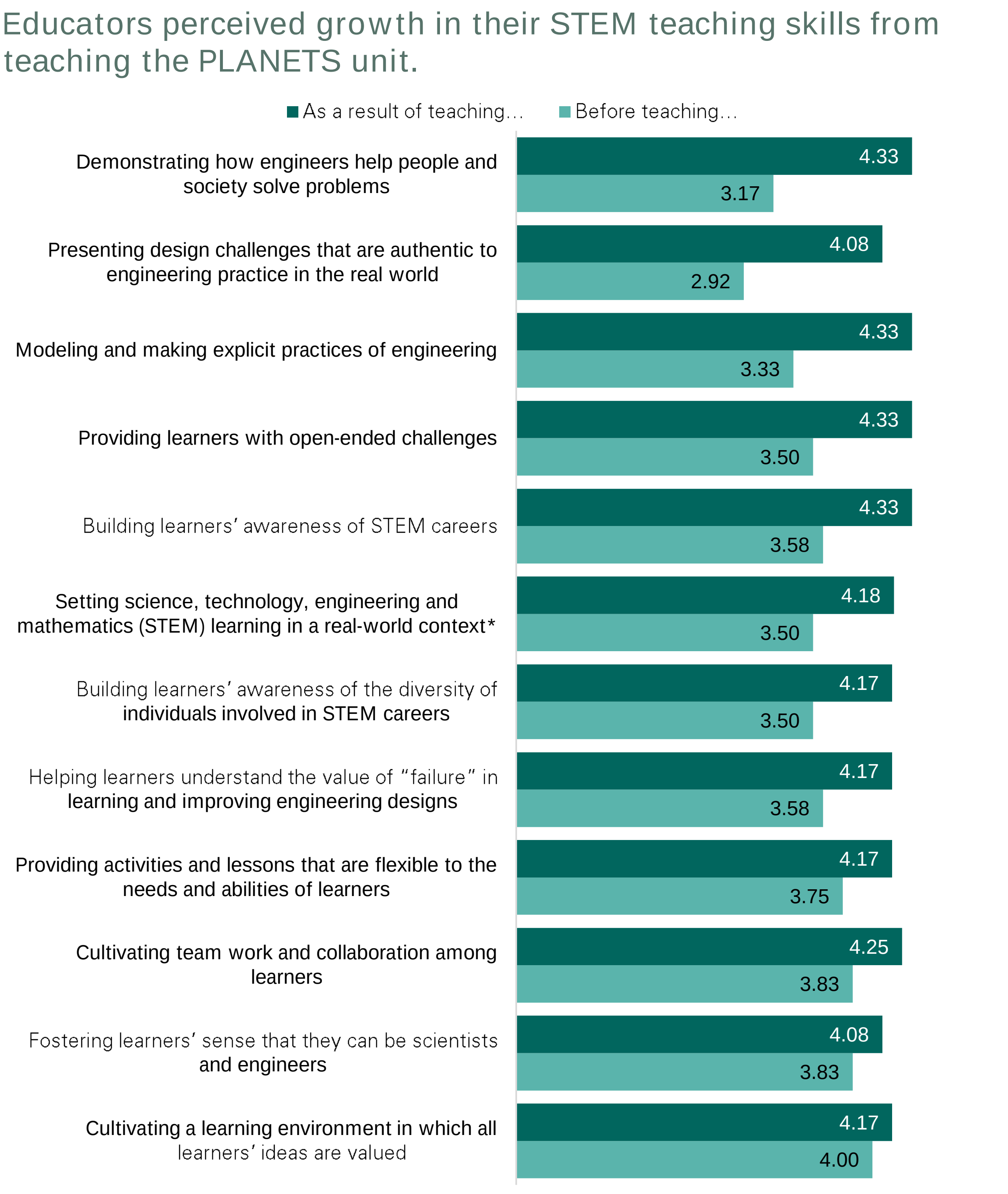

Figure 24. Teachers' reported pedagogy before and as a result of teaching the curriculum, on average (n = 12)

* As a result of teaching *Remote Sensing* (n = 11).

Educators perceived growth in their content knowledge from teaching the PLANETS units.

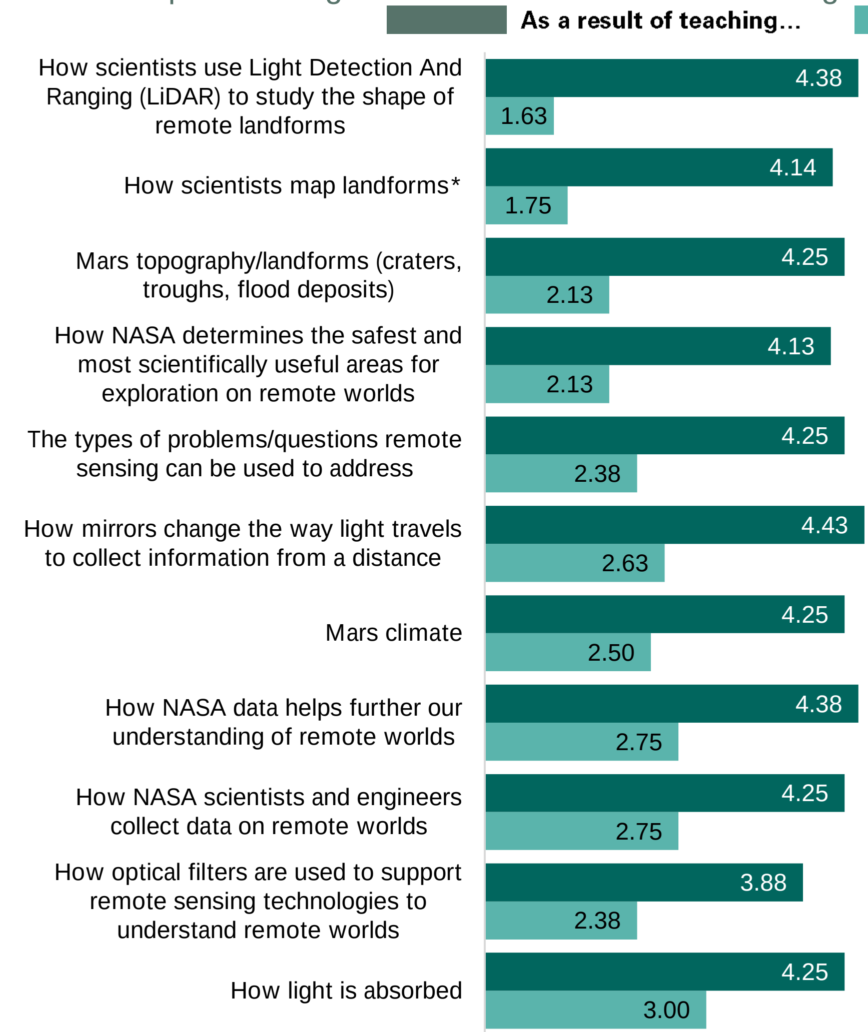

Figure 25. Teachers' reported content knowledge before and as a result of teaching *Remote Sensing*, on average (*n* = 8)

* As a result of teaching (*n* = 7).

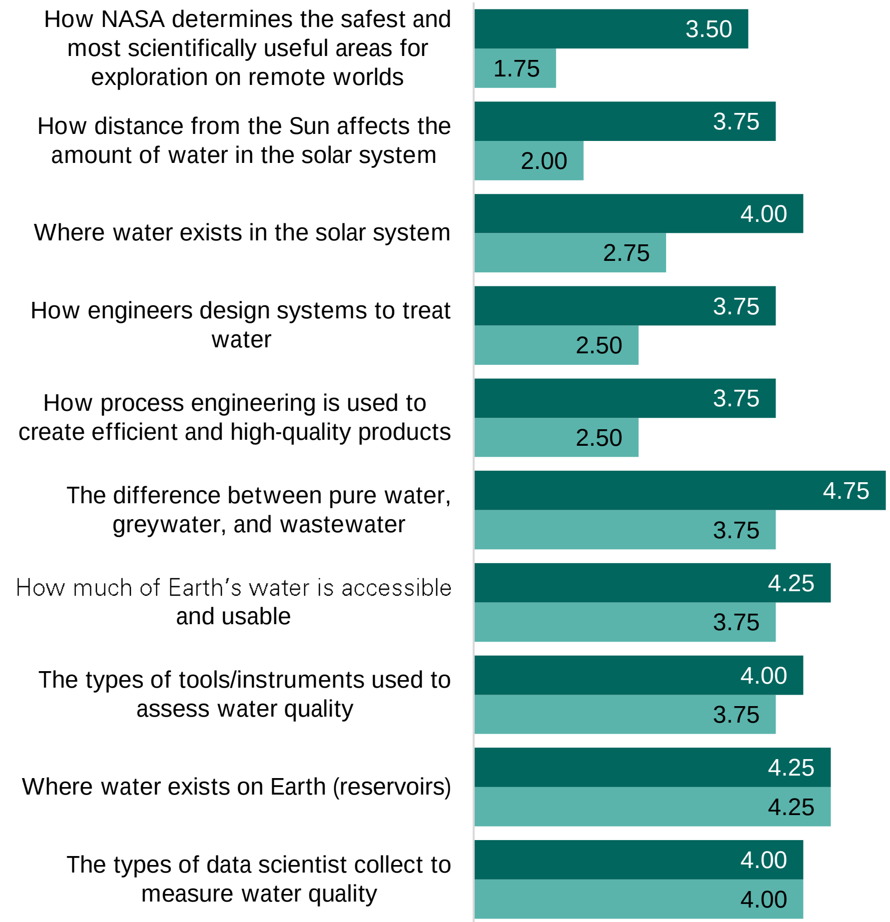

Figure 26. Teachers' reported content knowledge before and as a result of teaching *Water in Extreme Environments*, on average (*n* = 4)

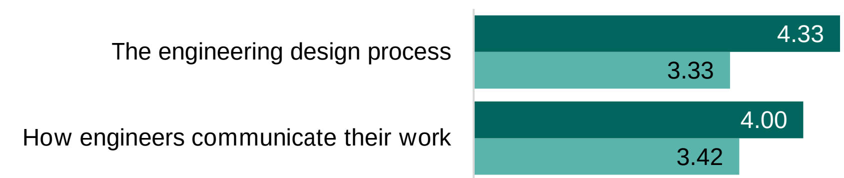

Figure 27. Teachers' reported engineering content knowledge before and as a result of teaching *Remote Sensing*, on average (*n* = 12)

Objective 4: Disseminate Curriculum, Educator Resources, and Knowledge on OST STEM Teaching and Learning

The PLANETS team recognized the importance of disseminating PLANETS products to further NASA's aims of enabling STEM education across the U.S. Therefore, the final PLANETS project objective was to widely disseminate (a) curricular and educator resources designed to increase access to and use of NASA assets, with particular attention to reaching underrepresented populations, and (b) knowledge regarding teaching and learning practices in OST activities gained as a result of the project. The following section describes the dissemination activities over the past 5 years of the project and then examines the extent to which the project has contributed to STEM education.

Dissemination via the MOS and PLANETS Websites

? To what extent and in what way did the project contribute to the body of high-quality materials in STEM education?

The PLANETS curriculum has primarily been disseminated through the MOS EiE website and the PLANETS website. Dissemination also occurred via the field tests and educator workshops discussed in other sections of this report. Via the two websites, educators can download complete engineering and science guides free of charge. MOS put the *Worlds Apart* and *Testing the Waters* engineering guides on the EiE website on January 26, 2018, and the *In Good Hands* guide on July 1, 2019. The PLANETS website went live in October 2019 with all science and engineering guides available for download. From 2018 through 2020, more than 5,000 guides were downloaded from the two websites (Table 3).

Table 3. Downloads of PLANETS engineering guides and/or science guides across the project years

PLANETS Downloads	Total Downloads 2018–2020
Remote Sensing	1,581
Water in Extreme Environments	2,969
Space Hazards	948
Total downloads	5,498

Website analytics for the downloads of all three engineering guides show a broad reach, with downloads from all 50 states and from Washington, D.C., and Puerto Rico.

Dissemination Through Conferences, Workshops, and Outreach Events

Across the 5 years, PLANETS team members shared PLANETS curricula, lessons learned, and research and evaluation findings at multiple conferences through posters, conference sessions, and exhibits or SciArt tables. In addition to sharing their work at national conferences, PLANETS partners hosted educator workshops and conducted general outreach activities (Figure 28). See Appendix M for a full list of dissemination activities across the years.

11 Unique Conferences

- **22 Conference Sessions**
- **17 Posters**
- **4 Convened Sessions**
- **2 Exhibits or SciAct Tables**

Examples:

- AGU
- Women in Space Conference
- Space Exploration Educators Conference
- BOOST Best of Out-Of-School-Time Conference
- Arizona Center for Afterschool Excellence Annual Meeting

10 Educator Workshops

Examples:

- Space Science Workshop
- Diné (Navajo) Education Science Institute
- ASU Mars Educator Workshop
- Universal Design for Learning
- Arizona Center for Afterschool Excellence

9 Outreach Activities

Examples:

- Flagstaff Community STEM Night at NAU Dome
- Tours of USGS Astrogeology and interactive sessions
- USGS Open House public STEM event
- Flagstaff Festival of Science

Figure 28. PLANETS dissemination activities

? To what extent and in what way did the project contribute to knowledge in the field of STEM education?

PLANETS researchers included PLANETS team members from NAU's CSTL and from MOS. The purpose of the research project was to investigate youth and educator experiences with engineering curricula in OST environments and identify how these experiences influence youth affiliation toward and identity with engineering (Clark, 2020b). Researchers hypothesized that if youth participate in well-facilitated innovative OST curricula, then they will build and develop science and engineering skills and knowledge, science understanding, and engineering habits of mind. Because effective educators are critical for successful learning experiences, NAU and MOS researchers also examined how educators facilitated these learning experiences. The following research questions guided the studies:

1. How do youth engage in engineering design during OST engineering instruction?
2. What engineering practices or *habits of mind* emerge as OST youth engage in engineering activities?
3. How do these habits of mind impact youth's interests and attitudes toward engineering?

Contribution to Knowledge

- ✓ Youth engage in certain engineering habits of mind through engagement with the engineering design process.
- ✓ Educators need resources that are targeted to their immediate needs.
- ✓ Educators need support for understanding the processes of science and engineering.
- ✓ Curriculum developers must consider OST contexts to develop useful and effective curricula for OST programs.

4. How is youth affiliation toward an identity with engineering impacted by participation in PLANETS?

Research sites included four OST programs for middle-school-age youth (two in Arizona; two in Massachusetts) and included four educators and 52 youth across the sites. The PLANETS research was approved by the Institutional Review Board at NAU and, for one site located on the Navajo Nation, by the Navajo Nation Research Review Board. Methods included audio and video recordings of OST educators and youth participating in PLANETS lessons, educator surveys, youth focus group interviews, the Engineering Interest and Attitudes survey, and youth participants' engineering journals. Key research findings revealed the following:

- Youth developed three engineering habits of mind and positive interest and attitudes toward engineering (discussed in earlier sections of this report).
- Educators implemented PLANETS lessons in ways aligned to their goals for OST youth, including providing opportunities for development of youth agency, persistence, self-direction, and interest.
- A curriculum built on the practices of engineering can foster connections between home, community, peers, and learning for diverse youth (third spaces).

For a complete description of the research and findings, see Clark (2020b) and conference papers and publications cited in Appendix M.

Overall, PLANETS research activities contributed to the field by providing insights into STEM teaching and learning in OST settings, which are very different from formal classroom learning environments.

Implications for educators cited by the NAU and MOS researchers include:

- Use of engineering curricula that emphasize engineering design can shape youth attitudes toward STEM.
- Youth need time to fully explore and engage in engineering practices to support STEM engagement and attitudes.
- Educators should use ways to welcome youth to STEM learning, including connections to third spaces and a focus on youth knowledge to build relevancy.

Implications for OST educator resources include:

- Educator support should be targeted to meeting educators' immediate information needs so they are prepared to teach STEM lessons.
- Educators need support for distinguishing between the epistemic practices of science vs. engineering.
- Educators need a deeper understanding of key science and engineering concepts in the unit, and greater recognition of the importance of pedagogical strategies such as closure and reflection following an activity.

Implications for curriculum developers include:

- The curriculum developer must also consider the scaffolding necessary to support educators' understanding of engineering practices and their importance as they relate to attitude and affiliation.
- OST environments differ from formal classroom environments, and curriculum developers need to understand the context of teaching and learning in OST environments to design effective curricula.
- OST educators may have limited scientific knowledge, so it is essential to include accessible content knowledge background information in the materials.

PLANETS Partners' Perceptions of Project Outcomes

In final Year 5 interviews, PLANETS partners reflected on the original vision for the work, how it played out across the years, and how well they felt PLANETS met its four objectives. PLANETS partners felt that the project accomplished the objectives of creating useful curricular units that leveraged NASA assets for use in out-of-school-time settings. Several partners noted, however, that the initial vision for the work was to create curricular units with science and engineering embedded in one guide, but the end product was separate engineering and science guides for each unit. This was necessitated by the need to keep engineering separate for MOS to include with its EiE series. As one partner commented,

> *We are reaching our informal audiences and I believe our educational resources are completely aligned to what we intended because we are helping educators to use the materials.*
>
> —PLANETS Partner Interview

> *In the end, the products align with the original vision in a broad sense. If we got into the details of the original vision of what it was supposed to look like in terms of an integrated STEM curriculum and professional development resources, it had some changes along the way where it looks a little bit different and it has several moving parts rather than one cohesive product that's come out of it.*

Partners commented on the need to continue the work to ensure that the materials are relatable and accessible for a more diverse audience. As one partner put it,

> *Essentially PLANETS 1.0 has done a lot of the hard legwork of testing and figuring out core components and approaches, and being able to build the capacity of partnership in understanding the next steps needed to improve those products for education for groups accessing it, as well as broaden the reach of what individuals or populations do access it.*

Findings Related to NASA's Top-Level Objectives

? To what extent did the project contribute to NASA's top-level objectives for education?

NASA SMD's goals and objectives seek to integrate NASA assets into science education. The top-level objectives for SMD are:

- Enabling STEM education
- Improving U.S. scientific literacy
- Advancing national education goals
- Leveraging efforts through partnerships

The SciAct initiative was designed to support these objectives, and evaluators have tracked the contribution of the PLANETS project to NASA's objectives. PLANETS progress toward these objectives is presented in this section of the report. Refer to Appendix N for details regarding the alignment of PLANETS objectives to NASA's top-level objectives.

PLANETS Contributions to NASA's Top-Level Objectives

✓ 1: Contributed to enabling STEM education by creating, testing, and disseminating 3 units, directly reaching over 5,000 educators and youth and potentially reaching 38,000 youth indirectly through materials downloads

✓ 2: Demonstrated that youth showed statistically significant increases in engineering interest and attitudes from participating in PLANETS units

✓ 3: Increased public engagement of STEM through NASA-themed curricular units reaching thousands of educators and youth

✓ 4: Leveraged expertise of organizational partners in development and dissemination

NASA Top-Level Objective 1: Enabling STEM Education

NASA supports the nation's STEM education efforts through "scientific content, access to subject matter experts (SMEs), use of education professionals, and access to authentic participatory access-to-space opportunities" (National Aeronautics and Space Administration [NASA], 2015). In support of this top-level objective, PLANETS enabled STEM education through the development of curricular units (PLANETS Objective 2). Curricula were developed in partnerships between USGS scientists (SMEs), MOS curriculum developers, and professional development staff at NAU (education professionals). Curricular units explicitly built ties to planetary science and exploration. Table 4 presents PLANETS progress aligned to NASA Top-Level Objective 1.

Table 4. PLANETS activities, metrics, and progress toward NASA Top-Level Objective 1

Project Activities	Metrics	Progress
Create, pilot, and disseminate 3 OST engineering units and 3 complementary planetary science extension units for implementation in all 50 states.	Involve at least 5 NASA science experts in the development of units.	8 SMEs contributed to the development and review of PLANETS products.
	Pilot-test units nationally with 80 OST educators and 800 youth, at least 25% from underrepresented populations.	113 educators and 2,164 youth participated in PLANETS through pilot testing. An average of 49% of these youth were from minority populations. *Space Hazards* pilot testing in 2020 was interrupted due to COVID-19.
	Disseminate at least 100 PLANETS units via the MOS and PLANETS websites per year, beginning in 2018.	5,400 PLANETS guides have been downloaded since 2018. To date, approximately 2,700 PLANETS educators and 3,245 youth have been directly contacted, 45% from underrepresented populations.
Conduct research with youth and OST educators to examine (a) how OST materials affect youth engineering attitudes and thinking and (b) how educators support youth in STEM learning experiences. Conduct national field tests of all PLANETS products, including curricular guides and educator resources.	Collect and analyze research data on implementation of middle school units at OST sites, 2 in Massachusetts and 2 in Arizona, with 4 educators and 20 youth, 50% from underrepresented groups. Collect and analyze field test data on implementation of all units and educator resources. Gather data on educator perceptions of materials, educator learning, youth interest and attitudes, and demographics on educators and youth.	Research was conducted at 4 OST sites with 52 youth, with 25% of educators and 42% of youth from underrepresented groups. Field tests of the *Remote Sensing* and *Water in Extreme Environments* units were conducted with 15 educators at 11 OST sites serving high populations of underserved minority youth. The field test for the *Space Hazards* unit began in January 2021 with 4 educators at 4 OST sites.
Respond to COVID-19 by developing PLANETS@Home.	Develop 1 family activity per PLANETS unit. Disseminate regionally and nationally.	Distributed 600 STEM bags regionally and 249 STEM bags nationally to 57% underserved families in 18 states, plus Puerto Rico.
Create, pilot, and disseminate educator resources for OST educators related to the 3 PLANETS units.	Involve at least 5 NASA science experts as partners in the development of educator resources.	8 SMEs contributed to the development and review of PLANETS educator resources.
	Co-create/pilot educator resources with 50 OST educators per year beginning in 2018, with 25% serving underrepresented youth.	5 educator resource development workshops were held with a total of 54 educators, serving 23% underrepresented populations.
	Disseminate educator resources to 100 OST educators per year, beginning in 2019.	2,500+ educators were directly reached and over 5,000 indirectly reached through dissemination.

PLANETS Reach

Across the 5 years of the project, PLANETS has reached adults and youth directly through face-to-face workshops, events, and activities. PLANETS has also reached adults and youth indirectly via the MOS EiE website and through the PLANETS website, where educators have accessed and downloaded the science and engineering guides.

Direct Participant Reach

Across the 5 years of the project, more than 2,600 adults directly participated in PLANETS through workshops, pilot tests, research, field tests, conference sessions, and public outreach sessions. Youth participants included over 3,000 learners who directly participated in pilot testing, field testing, and outreach activities. Table 5 shows direct adult and youth participation in PLANETS across the 5 years of the project.

Table 5. Adult and youth participation in PLANETS activities and outreach

	Adults	Youth
Year 1	316	518
Year 2	279	377
Year 3	477	506
Year 4	1,163	1,537
Year 5	451	300
Total	2,686	3,238

Indirect Participant Reach

While it is beyond the scope of the project to track whether downloaded units result in their use, the PLANETS team has conservatively estimated the indirect reach of PLANETS via downloads of the engineering and science educator guides. The team uses the formula for calculating indirect reach that MOS has used through years of experience to calculate reach of its EiE downloads. MOS conservatively estimates from past experience that half of the Engineering Adventure (EA) and Engineering Everywhere (EE) guides downloaded get used during the first year after download, and half of those get used again the second year. MOS assumes that downloaded guides do *not* get used after 2 years. Using these conservative estimates and based on downloads of PLANETS unit materials from the MOS and PLANETS websites, PLANETS guides have indirectly reached more than 38,000 youth through curriculum downloads across all 50 states and Puerto Rico.

NASA Top-Level Objective 2: Improving U.S. Scientific Literacy

NASA SMD addresses issues related to scientific literacy through the interface between its science and engineering efforts and learners of all ages. PLANETS supported this NASA top-level objective through the development and implementation of OST curricular units and educator resources (PLANETS Objectives 2 and 3). Table 6 presents PLANETS progress aligned to NASA Top-Level Objective 2.

Table 6. PLANETS activities, metrics, and progress toward NASA Top-Level Objective 2

Project Activities	Metrics	Progress
Youth who participate in engineering unit research and field testing in Years 4 and 5 take the Engineering Interest and Attitudes (EIA) survey.	Youth show a statistically significant gain in interest and attitudes toward engineering after participating in PLANETS units, as measured by the EIA survey.	Across pilot tests of the 3 engineering units, youth showed a statistically significant increase in interest and attitudes toward engineering, as measured by the EIA survey. Across field tests of the 2 engineering units, youth showed a statistically significant increase in interest and attitudes toward engineering, as measured by the EIA survey.
In Years 4 and 5, educators participated in a field study to determine the effect of the PLANETS units and associated educator resources on educators' knowledge and skills.	OST educators show a statistically significant gain in knowledge and skills related to professional development and pedagogy, as measured in field tests. Educator survey and interview data provide qualitative support for educator change in knowledge.	After completing the *Remote Sensing* and *Water in Extreme Environments* units, educators participating in the field test perceived increases in their content knowledge and instructional practices.

NASA Top-Level Objective 3: Advancing National Education Goals

NASA advances national education goals through the support of projects to improve STEM instruction, increase and sustain youth and public engagement in STEM, enhance STEM experiences for undergraduates, and better serve populations that are historically underrepresented in STEM (NASA, 2015). PLANETS advances national education goals through educator resource development efforts with OST providers (PLANETS Objective 3) and through dissemination of curricular products to youth from underrepresented populations, primarily Native American communities (PLANETS Objective 2). The PLANETS curriculum seeks to increase educator and youth engagement in STEM by leveraging the excitement of NASA missions, activities, and resources. Table 7 presents PLANETS progress aligned to NASA Top-Level Objective 3.

Table 7. PLANETS activities, metrics, and progress toward NASA Top-Level Objective 3

Project Activities	Metrics	Progress
PLANETS provides authentic STEM activities for youth through 3 OST engineering guides and 3 complementary planetary science guides. PLANETS pilot-tests STEM units nationally with underserved youth.	Pilot-test units nationally with 80 OST educators and 800 youth, at least 25% of whom are from underrepresented populations. Conduct research with 4 educators and approximately 60 OST youth, at least 25% of whom are from underrepresented populations.	Through October 2019, 113 educators and 2,164 youth participated in PLANETS through pilot testing. An average of 49% of these youth were from underrepresented populations. As of October 2019, all research data were collected at 4 OST sites—2 in Massachusetts and 2 in Arizona—with 52 youth. 25% of educators and 42%

	Field-test units with 40 OST educators and 700 youth, at least 25% of whom are from underrepresented populations.	of youth were from underrepresented groups. 2 of 3 field studies for the PLANETS units occurred, with *Remote Sensing* in fall 2019 and *Water in Extreme Environments* in fall 2020, with 15 educators at 11 OST sites in 9 states. The third field test, for *Space Hazards*, began in spring 2021 with 4 educators at 4 OST sites across 4 states.
PLANETS presents products and research at local, regional, state, and national venues to promote high-quality STEM learning and engagement.	Disseminate at least 100 PLANETS units per year via MOS and PLANETS websites, beginning in 2018. Disseminate educator resources to 100 OST educators per year.	As of November 2020, 4,467 PLANETS guides have been downloaded in all 50 states, the District of Columbia, and Puerto Rico. There have been 7,167 educators and 38,245 youth reached directly or indirectly. There have been 860 families reached through COVID-19 activities.
PLANETS pilot-tests STEM units nationally with underserved youth. PLANETS conducts research on how OST STEM is enhanced with PLANETS units at 4 sites: 2 in Arizona and 2 in Massachusetts. PLANETS conducts a national field test of all PLANETS products.	Pilot-test units nationally with 80 OST educators and 800 youth, at least 25% of whom are from underrepresented populations. Field-test units with 40 educators and 700 youth, at least 25% of whom are from underrepresented populations.	Through October 2019, 113 educators and 2,164 youth participated in PLANETS through pilot testing. An average of 49% of the youth were from underrepresented populations (pilot testing in 2020 was interrupted due to COVID-19). As of October 2019, all research data had been collected at 4 OST sites, 2 in Massachusetts and 2 in Arizona, with 52 youth. 25% of educators and 42% of youth were from underrepresented groups, including youth on the Navajo Nation. 2 of 3 field studies for the PLANETS units occurred, with *Remote Sensing* in fall 2019 and *Water in Extreme Environments* in fall 2020, with 15 educators at 11 OST sites. The third field test, for *Space Hazards*, began in spring 2021 with 4 educators at 4 OST sites. Across field tests, 73% of youth were underrepresented minority, and 73% were low income.
PLANETS develops educator resources delivered online through the PLANETS website.	Disseminate educator resources to 100 OST educators per year, beginning in 2019, with a target of at least 25% from or serving underrepresented groups.	As of November 2020, there had been 355 downloads of educator resources and 2,200 website users. 11 educators accessed the educator resources during the fall 2019 and fall 2020 field tests.

NASA Top-Level Objective 4: Leveraging Efforts Through Partnerships

NASA supports the leveraging of education efforts and assets by enabling collaborative activities among SciAct awardees (NASA, 2015). PLANETS leveraged partnerships through the unique collaborative project team of university educator resource development providers, USGS SMEs, MOS curriculum developers, and OST networks (PLANETS Objective 1). Table 8 presents PLANETS progress aligned to NASA Top-Level Objective 4.

Table 8. PLANETS activities, metrics, and progress toward NASA Top-Level Objective 4

Project Activities	Metrics	Progress
PLANETS partners include USGS Astrogeology Science Center scientists and EiE at the Museum of Science, Boston	PLANETS will increase by 10% the number of new collaborations formed, as well as the nature and duration of those collaborations.	Across the years, PLANETS engaged partners from 9 organizations and collaborated through pilot, research, and field test sites, exceeding the goal of a 10% increase.

In addition to the PLANETS team cross-organizational partnerships, the project engaged partners across Arizona. These included:

- Lowell Observatory (Apollo moon landing anniversary and curriculum)
- AzCASE (Educator workshops)
- Flagstaff STEM City (Marketing)
- Institute for Tribal Environmental Professionals
- Flagstaff Festival of Science (COVID response: STEM bags)
- Boys & Girls Club of Flagstaff (COVID response: STEM bags)
- Flagstaff Family Food Center (COVID response: STEM bags)
- Second Mesa Day School (COVID response: STEM bags)

The PLANETS team also engaged educational partners from OST programs across the U.S. through field tests (n = 11), pilot sites (n = 75), and research sites (n = 4). Through outreach, the project included 96 partners across the 5 years. PLANETS partners also leveraged partnerships through cross-collaborations with other NASA SciAct grantees. Collaborations included work across projects with the following:

- NISE (National Informal STEM Education) Network
- Northwest Earth and Space Sciences Pipeline at University of Washington
- Arctic and Earth STEM Integrating GLOBE and NASA at University of Alaska Fairbanks
- Infiniscope at Arizona State University
- National Institute of Aerospace NASA eClips
- Earth to Sky
- Museum Alliance
- Lunar and Planetary Institute
- AstroCamp
- NASA Astromaterials
- NASA Lunar and Planetary Mapping and Modeling Project
- NASA@ My Library
- Challenger Center

Summary and Discussion

PLANETS had four objectives: (a) modeling an interdisciplinary partnership to create high-quality curricular materials, (b) developing nationally available curricular units to reach underserved populations, (c) creating useful educator resources to support implementation of the units, and (d) disseminating PLANETS products and research findings to a national audience.

With respect to the interdisciplinary partnership, the PLANETS team overcame early challenges related to communication, roles, and responsibilities to become a highly functioning collaborative partnership with a shared vision for the work and a sense of unique purpose. Across all years of the project, partners consistently noted that the work of creating and disseminating the units and educator resources could not have been done by one of the partner organizations alone. The diversity and particular areas of expertise of each partner organization were necessary to accomplish the project goals. The health of the partnership was evident as the team responded to COVID-19 program closures and the new needs of families and educators during the pandemic. Had the pandemic-related obstacles occurred at an earlier stage of the partnership, the partners may not have had the cohesiveness to respond as effectively as they were able to with years of sustained and productive collaboration behind them.

Over the course of the project, the PLANETS team met its goal of creating three units—two for middle school youth and one for elementary youth—that were designed to reach educators and youth in out-of-school-time environments. Understanding that OST environments differ from formal classroom environments, the team built upon knowledge in the field and on partner expertise to design materials targeted to youth in afterschool or summer programs. Educators and project partners noted the need for materials to be engaging, so that the curriculum didn't "feel like school" and made STEM learning fun while simultaneously building skills and interests.

When enacted in pilot and field test sites, PLANETS lessons engaged students in engineering habits of mind, helping them learn to persist through failure and to work collaboratively to solve an engineering challenge. Youth in pilot and field test sites showed statistically significant increases in positive attitudes toward engineering as a result of their participation, suggesting that using an engineering design process involving collaboratively designing a solution to a challenge, testing the solution, and revising their design is an effective way to engage students in STEM learning. Educators also gained in their understanding of STEM content and instructional practices through participating in the curriculum.

Educator resources were developed and shared via the planets-stem.org website, and the team continues to revise and improve them. The PLANETS team is using formative feedback from field test sites to make the resources easier to access by tying them to individual lessons in the units. Use of educators to co-create the resources through educator workshops helped to ensure that the resources were useful to the targeted audiences. The team utilized NASA assets such as subject matter experts, videos, images, and data as a means of engaging learners in the units and providing exciting supplementary content for learners.

With respect to disseminating the curriculum and research findings to a national audience, PLANETS exceeded its original goals. Through workshops, pilot and field tests, and outreach, more than 2,500 adults and 3,000 youth were directly reached through the project, and thousands of others were potentially reached through downloads of the materials. Development of the PLANETS website, and links to the engineering guides on the MOS website, ensure sustainability of the materials over the years.

PLANETS leveraged community partners in northern Arizona, a statewide afterschool network in Arizona, and collaborations with other SciAct partners to help broaden the reach of the project. Additionally, a unique feature of PLANETS was to use NASA SMEs directly in development of the resources, which helped to ensure their accuracy and increased access to appropriate NASA assets.

In January 2021, PLANETS was awarded a 5-year extension (PLANETS 2.0) with a focus on enhancing the materials and educator resources to make them more accessible and useful to more diverse audiences, including youth with physical disabilities, English learners, and Native American youth. The team is committed to incorporating lessons learned from PLANETS 1.0 to ensure a collaborative and effective partnership for continued work.

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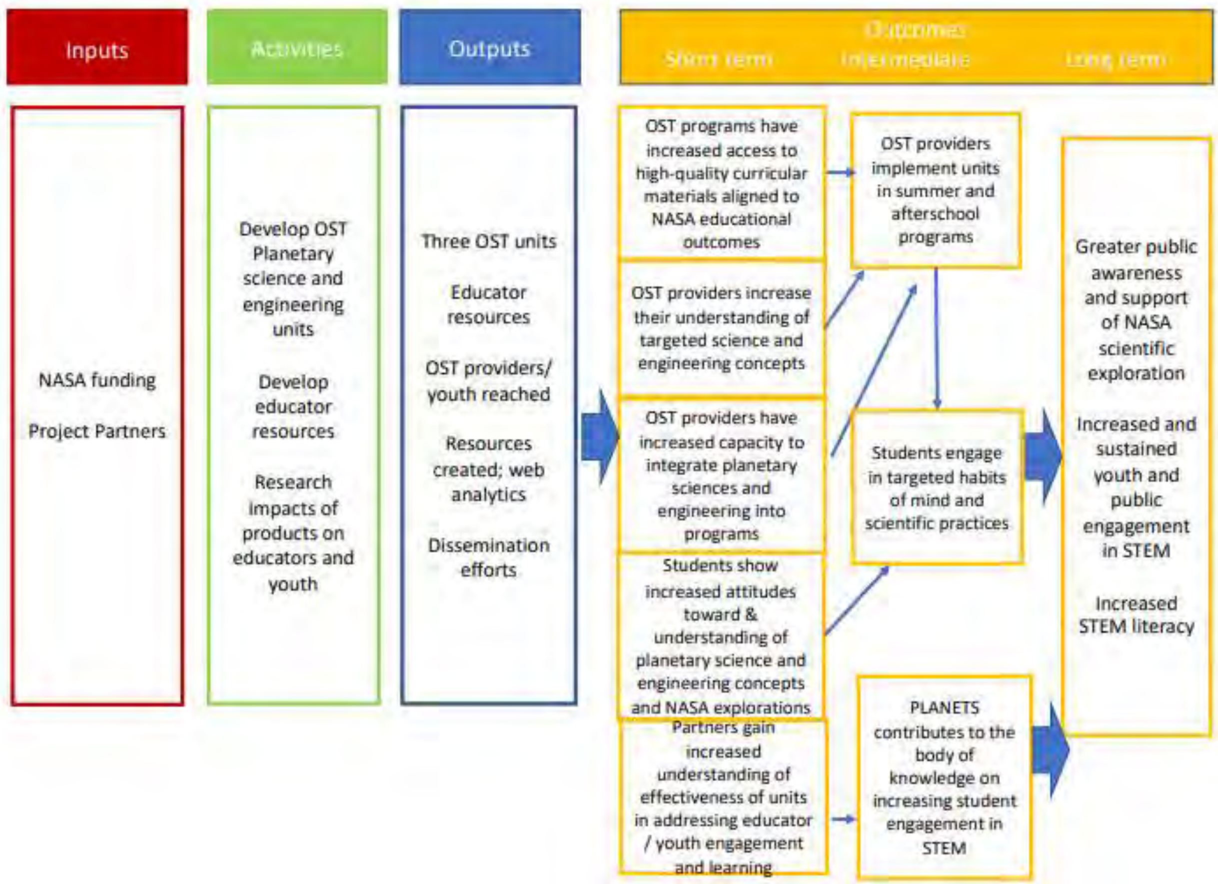
Appendix A: PLANETS Logic Model



Appendix B: Field Test Participant Sample

Field Test Participants

This section describes the samples for the two field tests. The final *Remote Sensing* youth sample included 11 educators and 92 youth, and the final *Water in Extreme Environments* EIA survey analysis sample included 4 educators and 71 youth. Below are flowcharts describing the sample for each unit.

Remote Sensing Sample Flowchart

FALL 2019

Onboarded:
8 sites
12 educators
251 youth

Attrition:
1 site
1 educator
20 youth

In Study:
7 sites
11 educators
231 youth

Site Demographics:[1]
Gender Girls: 50% Boys: 50%
Minority youth 81%
Economically disadvantaged youth 76%

Provided Classroom Data:
7 educators
126 youth

Missing Classroom Data[2]:
4 educators
105 youth
Missing Educator Data:
1 interview data
2 final implementation log
3 knowledge and skills survey

Removed from the Analysis Sample:
1 educator
34 youth (27%)

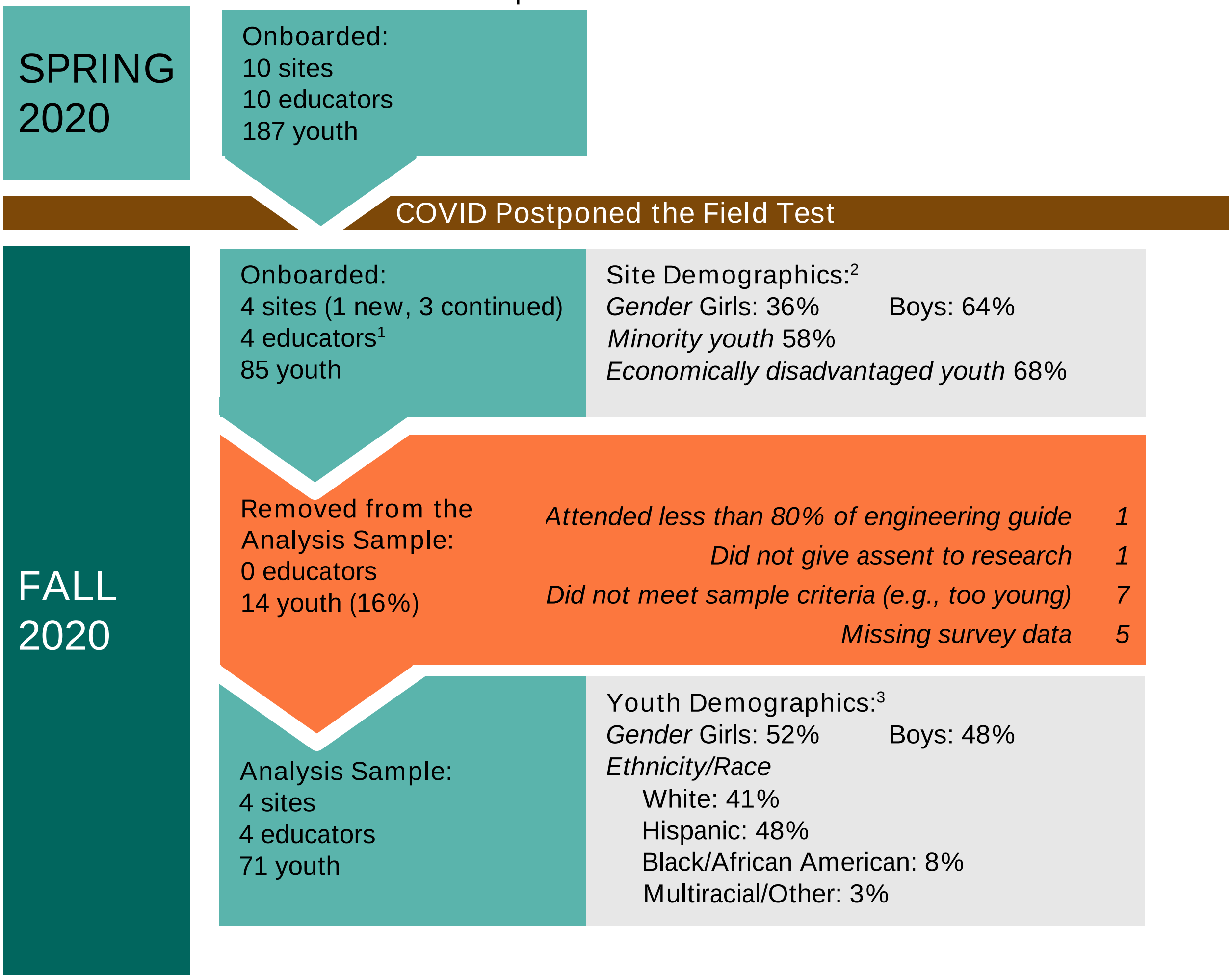
Attended less than 80% of engineering guide 25
Missing survey data 9

Analysis Sample:
7 sites
11 educators
92 youth

Youth Demographics:[3]
Gender Girls: 38% Boys: 54% Other: 8%
Ethnicity/Race
White: 24%
Hispanic: 12%
Black/African American: 47%
Asian: 7%
Multiracial: 11%

1. Demographic data averaged from study applications (one site used EIA demographic data because the site application did not provide clear information).
2. Three classrooms were not responsive from the start of the field test and provided limited data.
3. Demographic data from the final analysis sample.

Water in Extreme Environments Sample Flowchart



1. One site was no longer an OST site due to COVID. This educator provided the curriculum to a science class instead.
2. Demographic data averaged from site applications.
3. Demographic data from the final analysis sample.

Appendix C: PLANETS Evaluation Matrix

Table C1. PLANETS evaluation matrix

Formative Evaluation		
Evaluation Questions	**Data Sources & Timeline**	**Indicator/Metrics**
1. Are project partners meeting benchmarks for project development and implementation? 2. How well are partnerships working toward meeting project objectives? 3. What external factors are influencing project development and implementation?	Project partner interviews; Document review; Artifact review (Years 1–5)	Project partners work collaboratively to develop the program model and products. Project shows timely progress toward its intended outcomes.
4. What is the quality of materials produced through the project?	External review board; Materials evaluation rubrics (Years 1–2)	Materials demonstrate alignment to NASA STEM education goals, Next Generation Science Standards, and the National Research Council's K–12 Framework.
5. How well do educator resources support educators in implementing the units?	Educator resource feedback surveys; OST provider interviews (Years 3–5)	All OST providers feel prepared to implement the units.
6. To what extent and in what way do participating OST providers implement the units in their programs?	OST provider implementation survey; Observations/interviews (Years 3–5)	OST providers implement units with fidelity and successfully integrate them into their programs.

Summative Evaluation		
Evaluation Questions	**Data Sources & Timeline**	**Metrics**
1. Did the project meet its objectives to create high-quality curricula and educator resources for OST programs, through an effective partnership model for science education?	Benchmarking of key project activities and progress toward objectives	The project team completes project benchmarks on time, and adjusts processes and procedures based on formative evaluation findings.
2. What were the impacts of the partnership on project partners and their institutions?	Project partner interviews; Partner surveys	PLANETS partnership results in collaborative relationships that can support further work.
3. Did the program reach the target audience for the materials developed?	Program/participant demographics (Years 3–5)	Project reach includes greater than 50% underrepresented students and geographically diverse programs.
4. Did youth show more positive attitudes toward science and engineering as a result of participating? 5. Did youth show the ability to engage in targeted engineering	Engineering Interest and Attitudes survey; OST educator survey; educator interview; review of research findings;	Students show a statistically significant gain from pretest to posttest. Students show a high level of engagement.

	habits of mind as a result of participating?	observations of sample of programs (Years 4–5)	OST providers offer evidence and observations that document students' demonstration of targeted habits of mind.
6.	Did OST providers who used the educator resources increase their knowledge and skills related to the unit content and pedagogies?	Retrospective pretest for sample of OST providers; Sample of OST provider interviews (Years 4–5)	OST providers show a statistically significant gain in skills and abilities after using educator resources.
7.	To what extent and in what way did the project contribute to the body of high-quality materials in STEM education?	Review of dissemination efforts; Web analytics	Products are widely disseminated and used by the target audience.
8.	To what extent did the project contribute to knowledge in the field of STEM education?	Review of research findings; review of dissemination efforts	Research/evaluation findings are shared with the STEM education community.
9.	To what extent did the project contribute to NASA's top-level objectives for education?	Comparison of summative evaluation findings to NASA top-level objectives	PLANETS contributes in a meaningful way to NASA education objectives.

Appendix D: Evaluation Measures

Formative Evaluation Measures

Evaluators used a mix of literature review, surveys, interviews, document review, and observations to address evaluation questions related to the PLANETS project's progress toward its goals and objectives. A description of the measures follows.

Literature Review

In Year 1, Magnolia evaluators conducted a review of the literature to understand characteristics of effective partnerships. The literature review served to inform the development of survey items and interview questions related to partnership health and function.

PLANETS Partner Surveys

Evaluators administered partner surveys during Years 1–5 after whole-group and working-group meetings, concluding with an all-partner end-of-year survey. Survey items included a mix of Likert-scale and open-ended responses. The end-of-year partner survey (except in Year 4) included items from the Wilder Collaboration Factors Inventory (Mattessich, Murray-Close, & Monsey, 2001) that assessed aspects of partnership health, including communication, leadership, clear roles and responsibilities, common vision, and unique purpose. Partners also responded to a feedback survey about the annual Partner Working Group meeting.

In Year 4, evaluators implemented a reflection survey asking respondents to provide their feedback on project successes, project challenges, and hopes for continued work to set the stage for the PLANETS 2.0 proposal submission in spring 2020.

PLANETS Partner Interviews

In the summer or fall of each year of the project, evaluators conducted telephone interviews with the core PLANETS project team, including individuals from the PLANETS partner organizations. Interviews focused on how partners were collaborating within and across organizations on the PLANETS project, the impacts of the collaboration on organizational and individual learning, and areas of synergy and tension with partner organizations. Interviews lasted 30–40 minutes. Evaluators conducted final PLANETS 1.0 interviews with partners in summer 2020 to examine summative project impacts.

Educator Resource Development Workshop Survey

In Years 3 and 4, evaluators surveyed participants in the educator resource development workshops held to gather feedback on PLANETS materials to inform development of educator resources. The surveys contained a mix of Likert-scale and open-ended responses on the value of the workshops to participants and solicited feedback on the educator resource development process. These findings were used by the project team to inform website resources for unit implementation.

Document Review

In Years 1–4, evaluators examined program planning documents, drafts of curricular materials, and meeting notes to understand how work was progressing throughout implementation. Evaluators also viewed discussions and documents shared by PLANETS partners on Basecamp and later on Google Drive. Document review included review of annual reports and of the MOS curriculum pilot findings, project development notes, and research findings.

Meeting Observations

In Years 1–5, the lead evaluator attended and observed the annual PLANETS Partner Working Group meeting and participated in share-out teleconferences. The lead evaluator also attended the annual NASA SciAct meeting in Years 1–5.

Summative Evaluation Measures

Evaluators used multiple measures to examine the impacts of PLANETS on participating project partners, OST educators, and learners, and to understand how PLANETS products were contributing to the field of effective out-of-school-time STEM instruction. Measures included partner interviews and surveys, OST educator surveys, interviews and observations, an engineering attitudes survey for learners, website analytics, and tracking of dissemination efforts. A description of the measures follows.

PLANETS Partner Survey

The Year 5 Partner Working Group survey included items from the Wilder Collaboration Factors Inventory (Mattessich, Murray-Close, & Monsey, 2001) that assessed aspects of partnership health, including communication, leadership, clear roles and responsibilities, common vision, and unique purpose.

PLANETS Partner Interviews

In Year 5, evaluators conducted interviews with nine individuals from the three partner organizations to understand the impacts of the PLANETS collaboration on organizational and individual learning, and the benefits of participating in the project. Final interviews also provided partners with the opportunity to share their perceptions of PLANETS successes and challenges, discuss any unintended outcomes, document their contributions to PLANETS, and share their perceptions of how well the project met its intended outcomes. Year 5 interviews also included questions about how the project was impacted by COVID-19 and how PLANETS responded to educator and family needs during the pandemic.

OST Educator Interviews

Evaluators conducted telephone interviews with OST providers who used the PLANETS units with their students. Interviews lasted 30–40 minutes and gathered in-depth feedback on the materials and their impact on OST educators and learners.

OST Educator Implementation Survey

During field tests of the PLANETS curriculum, OST educators completed an online implementation survey after completing the unit with their learners. The survey contained a mix of Likert-scale and open-ended items. The survey asked educators about the time they spent preparing and teaching the unit, materials and resources they used with their learners, their perceptions of the quality and utility of the materials and any challenges they encountered, and their learners' engagement and learning.

OST Knowledge and Skills Survey

After completing the field test of the PLANETS unit, OST educators completed a survey to examine whether using the PLANETS materials impacted their knowledge of the topic and their pedagogy for teaching STEM. The survey contained a mix of Likert-scale and open-ended items.

Engineering Interest and Attitudes Survey

The Engineering Interest and Attitudes Survey (Cunningham & Lachapelle, 2010) was developed by researchers at MOS for use in studies of MOS's EiE curricula. The retrospective survey contains 19 items where youth rate their level of agreement with items related to their engineering interest and attitudes prior to and after participating in the engineering activities. The survey has 5 subscales: Aspirations, Enjoyment, School, Value to Me, and Value to Society.

Document Review

In Year 5, evaluators examined program planning documents, drafts of curricular materials, and meeting notes to understand implementation. Evaluators also viewed discussions and documents shared by PLANETS partners on Basecamp and Google Drive. Document review included review of PLANETS@Home meeting notes and planning documents, review of the final annual report, and review of the MOS curriculum pilot findings and research findings.

Website Analytics and Dissemination

In Year 4, evaluators began tracking downloads of the engineering guides via the MOS website. In Year 5, evaluators also documented access to the PLANETS website and downloads of curricular materials and PLANETS@Home activities.

Across all years, evaluators tracked project team dissemination of PLANETS materials, research, lessons learned, and contributions to the field of STEM OST. Dissemination tracking included conference presentations, posters, publications, and networking events.

Appendix E: Progress on PLANETS Objectives by Year

Objective 1: Model an Interdisciplinary Partnership

Task	Year 1	Year 2	Year 3	Year 4	Year 5
Monthly partner check-ins	◆	◆	◆	◆	◆
Site visits between PLANETS partners	◆	◆	◆	◆	◆
Google Drive document sharing	◆	◆	◆	◆	◆
Mutual use of formative evaluation findings	◆	◆	◆	◆	◆
Annual Partner Working Group meeting	◆	◆	◆	◆	◆

◆ = Complete → = In progress

Objective 2: Develop Nationally Available Curricular Units to Reach Underserved Populations

Task	Year 1	Year 2	Year 3	Year 4	Year 5
Develop 2 EE MS units	◆				
Pilot EE units	→	◆			
Finalize EE units		→	◆		
Develop EA unit	→	◆			
Pilot EA unit		→	◆		
Finalize EA unit			→	◆	
Develop Astronaut Training unit			→	◆	
Pilot Astronaut Training unit				◆	
Finalize Astronaut Training unit				→	◆
Develop MS Science Series	→	→	◆		
Pilot MS Science Series		→	◆		
Develop ES Science Series			→	→	◆
Pilot ES Science Series				→	→
Research with OST youth and educators		→	→	◆	
Curriculum field studies				→	→

◆ = Complete → = In progress

Objective 3: Create and Test Educator Resources

Task	Year 1	Year 2	Year 3	Year 4	Year 5
Conduct OST provider needs assessment	◆				
Coordinate OST outreach	→	→	→	→	◆
Design and develop materials	→	→	→	→	◆
Develop educator resources	→	→	→	→	◆
Pilot delivery of educator resources	→	→	→	→	◆
Finalize educator resources			→	→	◆
Field test study				→	→

◆ = Complete → = In progress

Objective 4: Disseminate Curriculum, Educator Resources, and Knowledge on OST STEM Teaching and Learning

Task	Year 1	Year 2	Year 3	Year 4	Year 5
Disseminate final curriculum products	→	→	→	→	◆
Disseminate educator resources	→	→	→	→	◆
Disseminate knowledge to the field	→	→	→	→	◆

◆ = Complete → = In progress

Appendix F: Annual Partner Working Group Survey Results

Table F1. Respondents' ratings on aspects of the annual Partner Working Group meeting by year*

	Year	N	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The meeting was a productive use of my time.	2016	10	0%	0%	0%	10%	90%
	2018	12	0%	0%	17%	33%	50%
	2019	11	0%	9%	0%	36%	55%
	2020	12	0%	0%	0%	42%	58%
Discussion at the meeting was productive.	2016	10	0%	0%	0%	40%	60%
	2018	11	0%	0%	0%	36%	64%
	2019	11	0%	9%	0%	55%	36%
	2020	12	0%	0%	8%	42%	50%
I felt that my contributions to the meeting were valued.	2016	10	0%	0%	10%	60%	30%
	2018	12	0%	0%	8%	25%	67%
	2019	11	0%	0%	9%	27%	64%
	2020	12	0%	0%	9%	27%	64%
The meeting fostered a sense of community among members.	2016	10	0%	0%	10%	10%	80%
	2018	12	0%	0%	0%	25%	75%
	2019	11	0%	0%	9%	18%	73%
	2020	12	0%	0%	0%	8%	92%
The meeting fostered clear communication among members.	2016	10	0%	0%	20%	40%	40%
	2018	12	0%	0%	8%	33%	58%
	2019	11	0%	0%	9%	27%	64%
	2020	12	0%	0%	8%	25%	67%
The meeting objectives were met.	2016	10	0%	0%	0%	40%	60%
I have clear understanding of next steps in our shared work.	2016	10	0%	0%	0%	70%	30%
	2018	12	0%	8%	8%	42%	42%
	2019	11	0%	9%	9%	9%	73%
	2020	12	0%	0%	8%	42%	50%

*Includes all project years except Year 2.

Table F2. Respondents' ratings of the Partner Working Group meeting characteristics by year

	Year	N	Poor	Fair	Average	Good	Excellent
Opportunities for participation and dialogue	2016	10	0%	0%	0%	40%	60%
	2017	16	0%	0%	6%	63%	31%
	2018	12	0%	0%	8%	17%	75%
Engaging the group in the work of the project	2016	10	0%	0%	0%	30%	70%
	2017	16	0%	0%	6%	50%	44%
	2018	12	0%	0%	0%	17%	83%

	2019	11	0%	0%	18%	36%	45%
	2020	12	0%	0%	17%	25%	58%
Incorporating multiple perspectives into planning and future work	2016	10	0%	0%	0%	50%	50%
	2017	16	0%	0%	6%	44%	50%
	2018	12	0%	0%	8%	8%	83%
	2019	11	0%	18%	0%	9%	73%
	2020	12	0%	0%	17%	17%	67%
Developing a shared repertoire of experiences	2016	10	0%	0%	0%	30%	70%
	2017	16	0%	0%	6%	56%	38%
	2018	12	0%	0%	0%	17%	83%
	2019	11	0%	18%	9%	27%	45%
	2020	12	0%	0%	0%	42%	58%
Creating connections across institutional and geographic boundaries	2016	10	0%	0%	0%	40%	60%
	2017	16	0%	0%	0%	44%	56%
	2018	12	0%	0%	0%	25%	75%
	2019	11	0%	18%	9%	27%	45%
	2020	12	0%	0%	0%	17%	83%
Moving the work of the project forward	2016	10	0%	0%	0%	50%	50%
	2017	16	0%	0%	6%	38%	56%
	2018	12	0%	0%	8%	33%	58%
	2019	11	0%	0%	18%	27%	55%
	2020	12	0%	0%	0%	50%	50%

Table F3. Respondents' ratings of the Partner Working Group meeting objectives by year

	Year	N	Poor	Fair	Average	Good	Excellent
Assessing progress on the project	2018	12	0%	0%	0%	25%	75%
	2019	11	0%	0%	9%	27%	64%
	2020	12	0%	0%	0%	42%	58%
Developing strategies for continuing work	2018	12	0%	8%	8%	33%	50%
Sharing products/data/lessons learned	2018	12	0%	0%	0%	33%	67%
	2019	11	0%	0%	0%	18%	82%
	2020	12	0%	0%	0%	42%	58%
Promoting a culture of inquiry and collaboration among partners	2018	12	0%	0%	0%	8%	92%
	2019	11	0%	0%	9%	18%	73%
	2020	12	0%	0%	0%	17%	83%
Developing a shared understanding of how PLANETS is addressing NASA's top-level indicators	2018	12	0%	0%	0%	50%	50%
Contributing to and understanding the role of evaluation in PLANETS	2019	11	0%	0%	18%	36%	45%
	2020	12	0%	0%	0%	58%	42%

Initiating a dialogue about moving forward with PLANETS 2.0	2019	11	0%	0%	9%	18%	73%

Appendix G: Factors in Collaboration

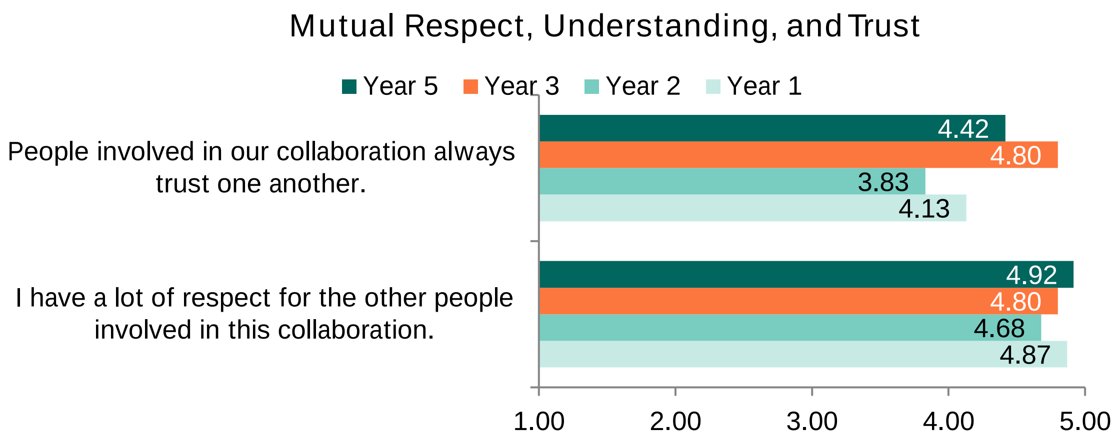
Taken from *Collaboration: What Makes It Work?* (Mattessich, Murray-Close, & Monsey, 2001).

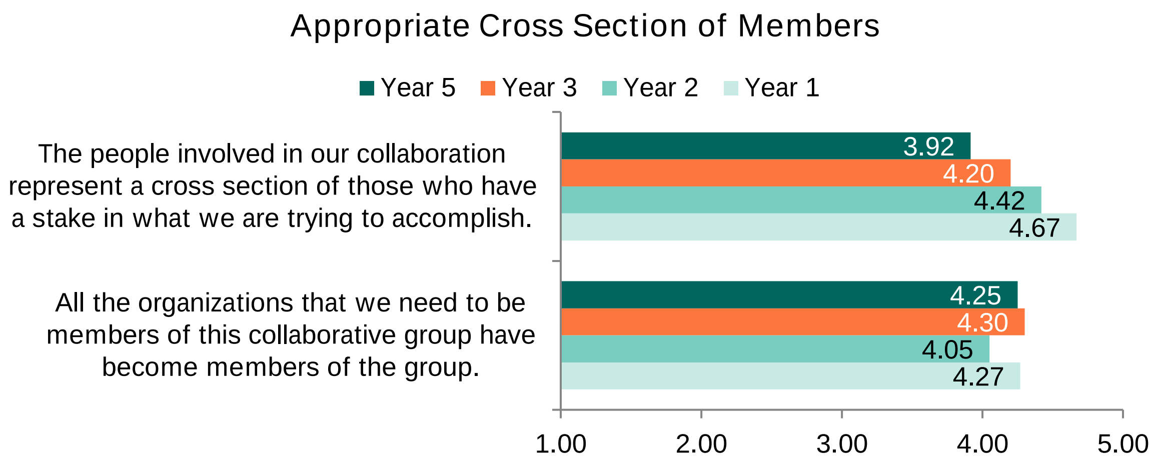
Table G1. Factors included in the Wilder Collaboration Factors Inventory

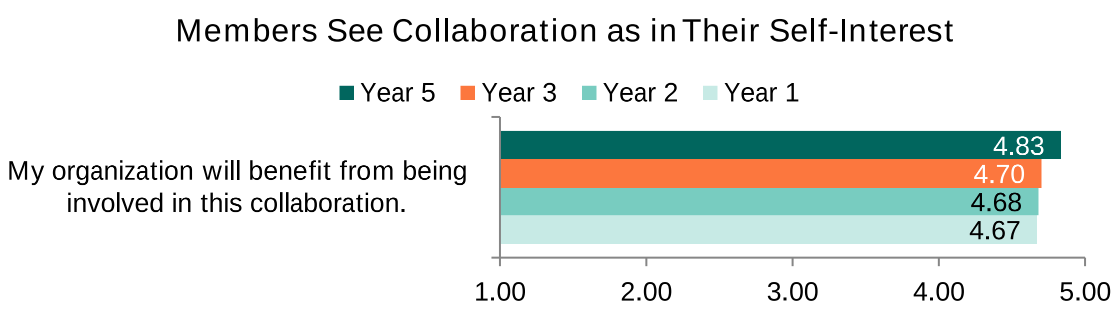
Factor	Description
Mutual respect, understanding, and trust	Members of the collaborative group share an understanding and respect for each other and their respective organizations: how they operate, their cultural norms and values, their limitations, and their expectations.
Appropriate cross section of members	To the extent that they are needed, the collaborative group includes representatives from each segment of the community that will be affected by its activities.
Members see collaboration as in their self-interest	Collaborating partners feel they will benefit from their involvement in the collaboration and that the advantages of membership will offset the costs.
Ability to compromise	Collaborating partners are able to compromise, since the many decisions within a collaborative effort cannot possibly fit the preferences of every member perfectly.
Shared stake in both process and outcome	Members of a collaborative group feel ownership of both the way the group works and the results of the work.
Multiple layers of participation	Every level within each partner organization has at least some representation and ongoing involvement in the collaborative initiative.
Flexibility	The collaborative group remains open to varied ways of organizing itself and accomplishing its work.
Clear roles and policy guidelines	The collaborating partners clearly understand their roles, rights, and responsibilities, and they understand how to carry out those responsibilities.
Appropriate pace of development	The structure, resources, and activities of the collaborative group change over time to meet the needs of the group without overwhelming its capacity at any point throughout the initiative.
Open and frequent communication	Collaborative group members interact often, update one another, discuss issues openly, and convey all necessary information to one another and to people outside the group.
Concrete, attainable goals and objectives	Goals and objectives of the collaborative group are clear to all partners and can realistically be attained.
Shared vision	Collaborating partners have the same vision, with a clearly agreed-upon mission, set of objectives, and strategy. The shared vision may exist at the outset of collaboration, or the partners may develop a vision as they work together.
Unique purpose	The mission and goals, or approach, of the collaborative group differ, at least in part from the mission and goals or approach of the member organizations.
Skilled leadership	The individual who provides leadership for the collaborative group has organizing and interpersonal skills and carries out the role with fairness. Because of these characteristics (and others), the leader is granted respect by collaborative partners.

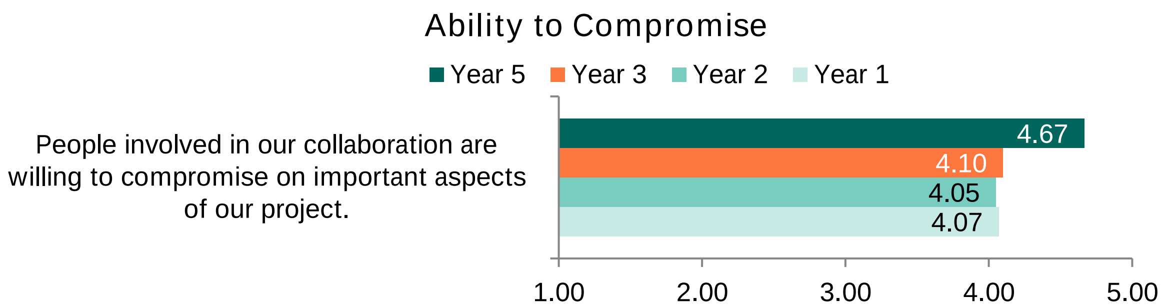
Appendix H: PLANETS Collaboration Survey Results, Years 1–3 and 5

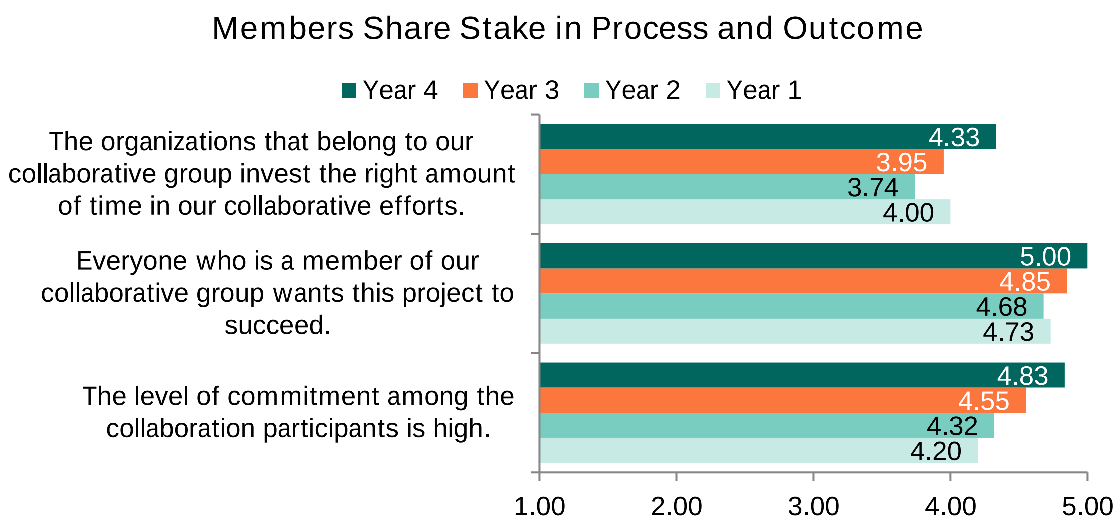
Taken from *Collaboration: What Makes It Work?* (Mattessich et al., 2001)

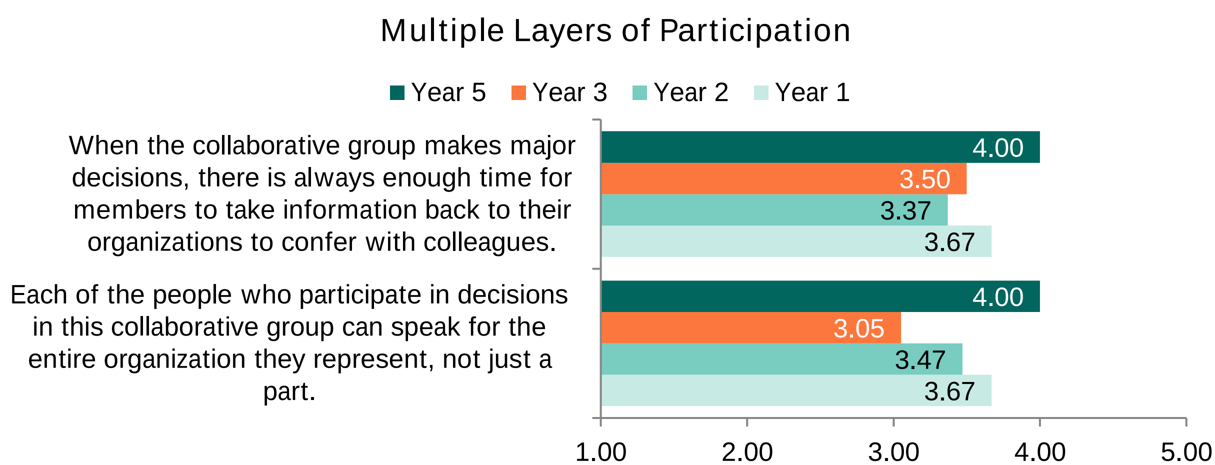


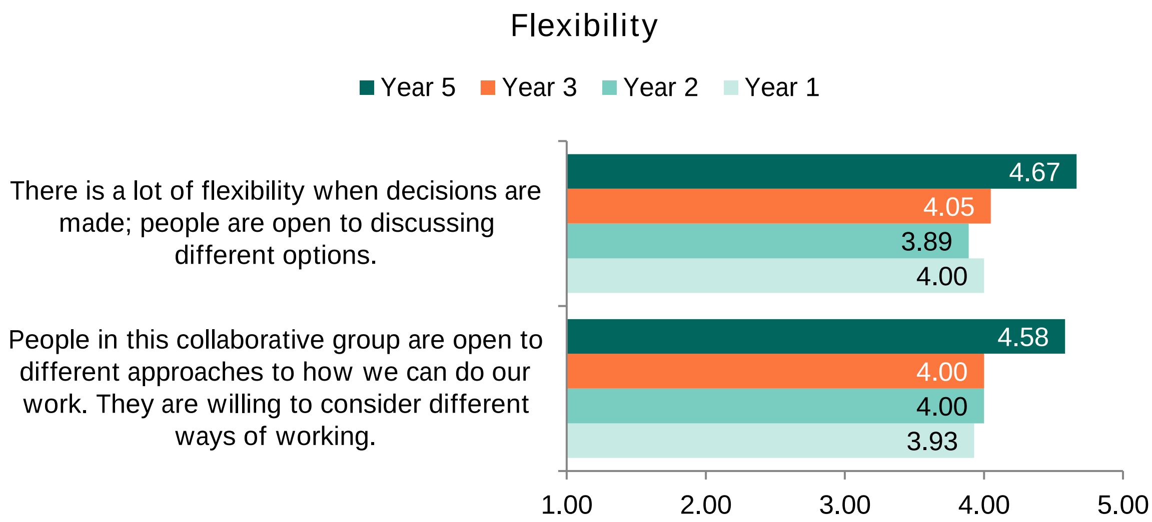


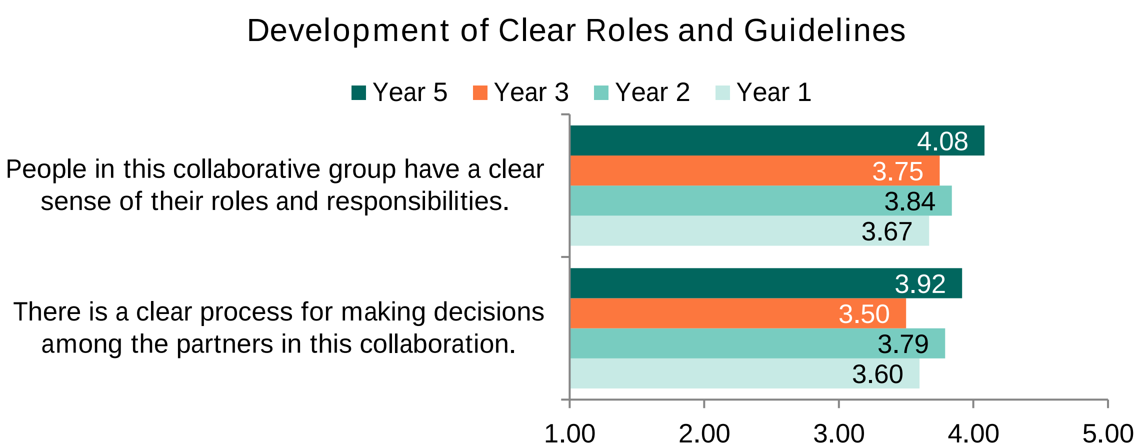


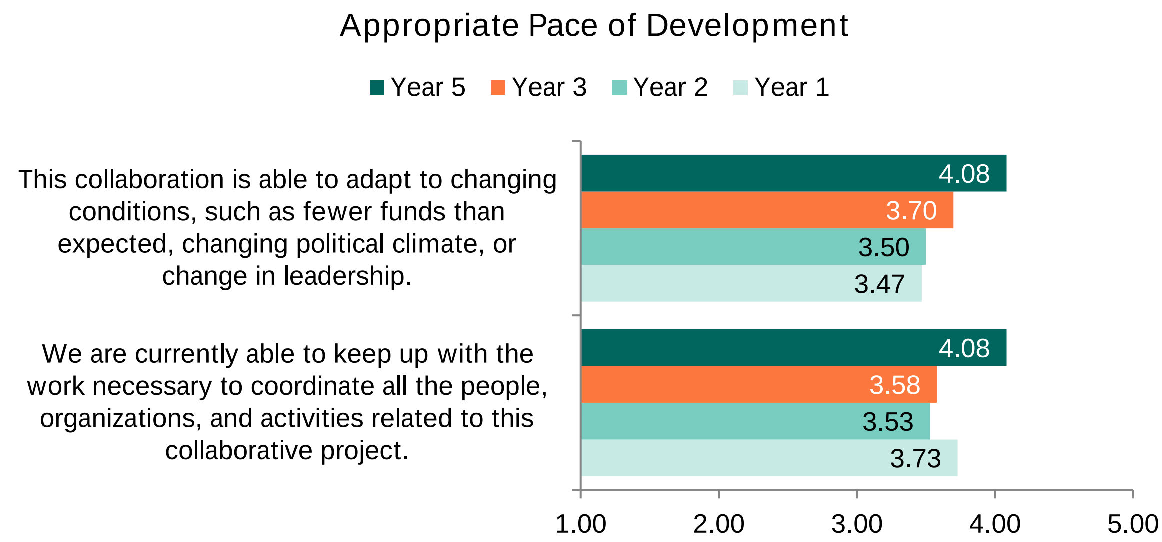

Ability to Compromise
Year 5
Year 3
Year 2
Year 1
People involved in our collaboration are willing to compromise on important aspects of our project.
4.67
4.10
4.05
4.07
1.00
2.00
3.00
4.00
5.00

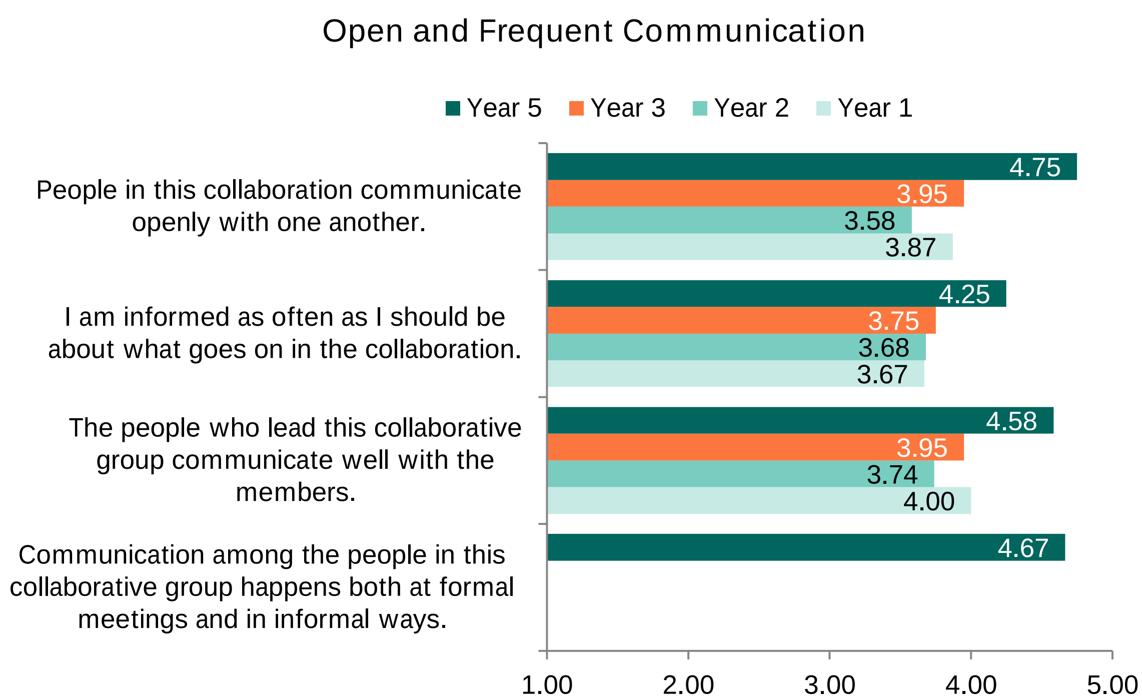

Members Share Stake in Process and Outcome
Year 4
Year 3
Year 2
Year 1
The organizations that belong to our collaborative group invest the right amount of time in our collaborative efforts.
4.33
3.95
3.74
4.00
Everyone who is a member of our collaborative group wants this project to succeed.
5.00
4.85
4.68
4.73
The level of commitment among the collaboration participants is high.
4.83
4.55
4.32
4.20
1.00
2.00
3.00
4.00
5.00

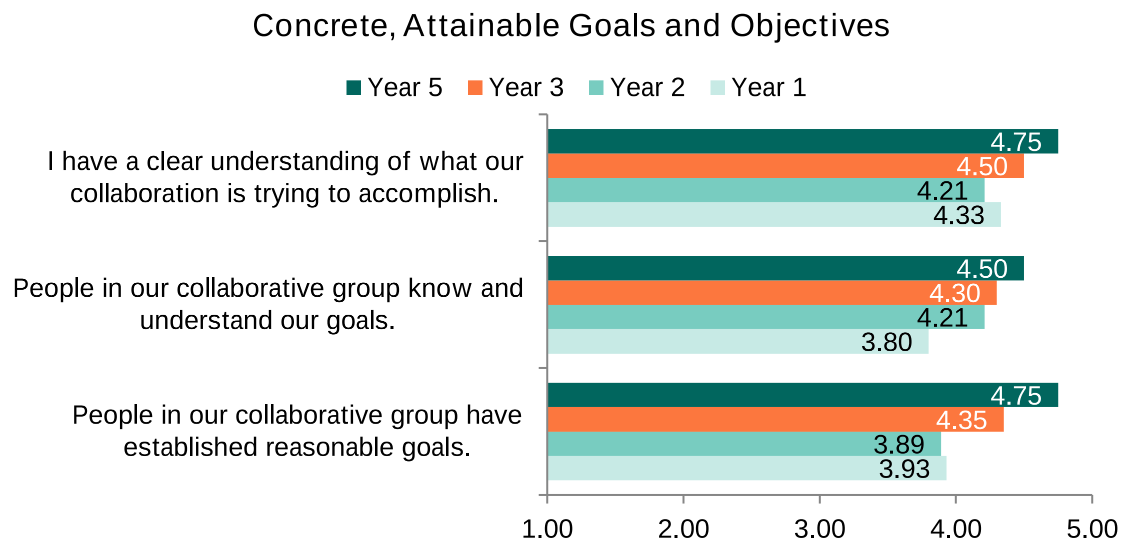

Multiple Layers of Participation
Year 5
Year 3
Year 2
Year 1
When the collaborative group makes major decisions, there is always enough time for members to take information back to their organizations to confer with colleagues.
4.00
3.50
3.37
3.67
Each of the people who participate in decisions in this collaborative group can speak for the entire organization they represent, not just a part.
4.00
3.05
3.47
3.67
1.00
2.00
3.00
4.00
5.00

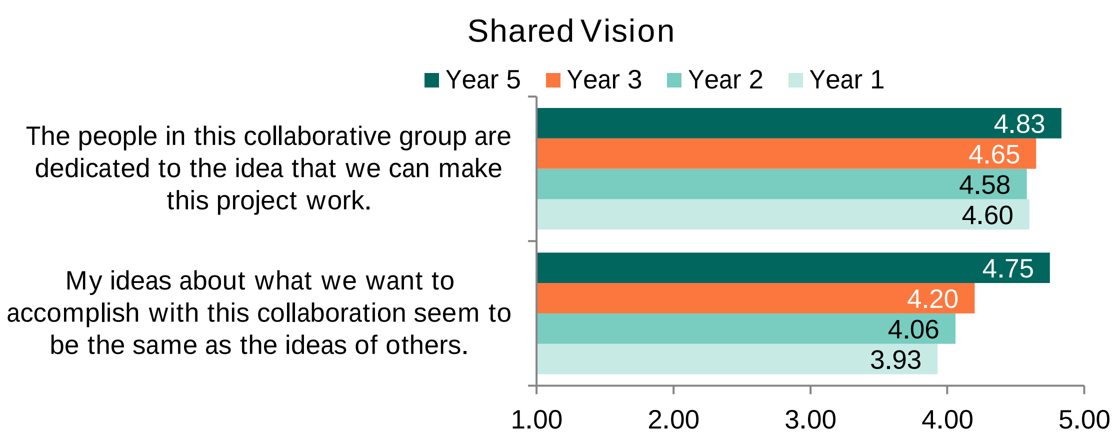

Flexibility
Year 5
Year 3
Year 2
Year 1
There is a lot of flexibility when decisions are made; people are open to discussing different options.
4.67
4.05
3.89
4.00
People in this collaborative group are open to different approaches to how we can do our work. They are willing to consider different ways of working.
4.58
4.00
4.00
3.93
1.00
2.00
3.00
4.00
5.00

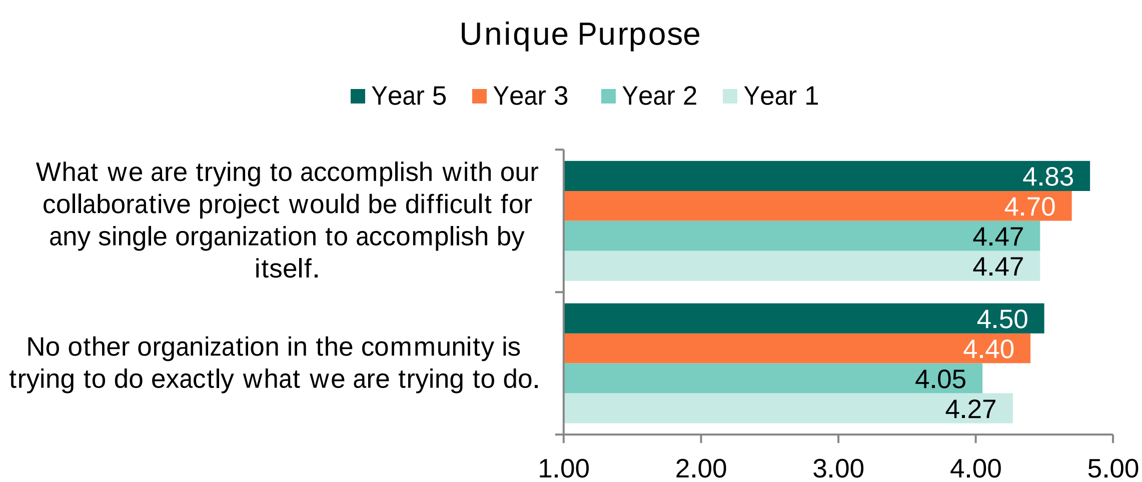

Development of Clear Roles and Guidelines
Year 5
Year 3
Year 2
Year 1
People in this collaborative group have a clear sense of their roles and responsibilities.
4.08
3.75
3.84
3.67
There is a clear process for making decisions among the partners in this collaboration.
3.92
3.50
3.79
3.60
1.00
2.00
3.00
4.00
5.00

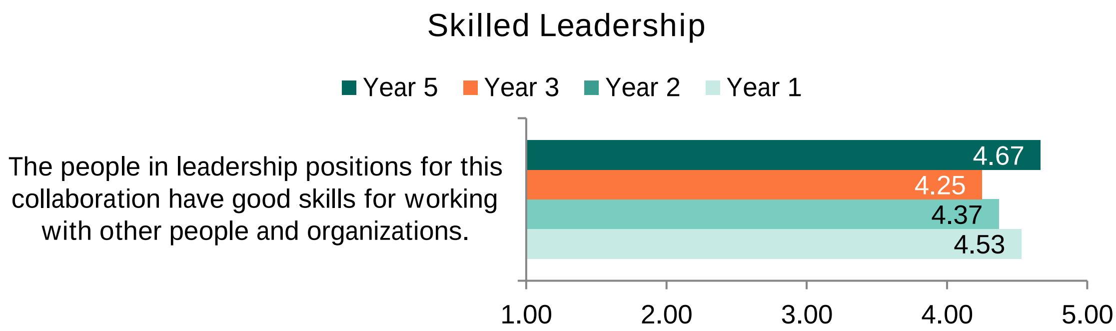

Appropriate Pace of Development
Year 5
Year 3
Year 2
Year 1
This collaboration is able to adapt to changing conditions, such as fewer funds than expected, changing political climate, or change in leadership.
4.08
3.70
3.50
3.47
We are currently able to keep up with the work necessary to coordinate all the people, organizations, and activities related to this collaborative project.
4.08
3.58
3.53
3.73
1.00
2.00
3.00
4.00
5.00


Open and Frequent Communication
Year 5
Year 3
Year 2
Year 1
People in this collaboration communicate openly with one another.
4.75
3.95
3.58
3.87
I am informed as often as I should be about what goes on in the collaboration.
4.25
3.75
3.68
3.67
The people who lead this collaborative group communicate well with the members.
4.58
3.95
3.74
4.00
Communication among the people in this collaborative group happens both at formal meetings and in informal ways.
4.67
1.00
2.00
3.00
4.00
5.00


Concrete, Attainable Goals and Objectives
Year 5
Year 3
Year 2
Year 1
I have a clear understanding of what our collaboration is trying to accomplish.
4.75
4.50
4.21
4.33
People in our collaborative group know and understand our goals.
4.50
4.30
4.21
3.80
People in our collaborative group have established reasonable goals.
4.75
4.35
3.89
3.93
1.00
2.00
3.00
4.00
5.00


Shared Vision
Year 5
Year 3
Year 2
Year 1
The people in this collaborative group are dedicated to the idea that we can make this project work.
4.83
4.65
4.58
4.60
My ideas about what we want to accomplish with this collaboration seem to be the same as the ideas of others.
4.75
4.20
4.06
3.93
1.00
2.00
3.00
4.00
5.00


Unique Purpose
Year 5
Year 3
Year 2
Year 1
What we are trying to accomplish with our collaborative project would be difficult for any single organization to accomplish by itself.
4.83
4.70
4.47
4.47
No other organization in the community is trying to do exactly what we are trying to do.
4.50
4.40
4.05
4.27
1.00
2.00
3.00
4.00
5.00


Skilled Leadership
Year 5
Year 3
Year 2
Year 1
The people in leadership positions for this collaboration have good skills for working with other people and organizations.
4.67
4.25
4.37
4.53
1.00
2.00
3.00
4.00
5.00

Appendix I: Incorporation of NASA Assets into the PLANETS Curriculum

Table I1. NASA assets and their location in the *Remote Sensing* PLANETS unit

Specific NASA datasets, spacecraft (ISS), partners (JPL) and/or missions	Where found/incorporated in unit (Engineering/Science; activity number)
• Special Report video filmed at JPL, Pasadena • Mars Reconnaissance Orbiter (MRO), 2005, specifically HiRISE camera and images • Mars Exploration Rover (MER) Opportunity and images of Victoria Crater • MOLA/topographic maps and globe of Mars • Artist renditions of Mars, orbiting satellites, and other missions	Engineering, *Worlds Apart*: What is Technology, Prep Activity 2
• Did you know fact about NASA, LiDAR reference Curiosity rover • Did you know fact about NASA planetary scientists and telescopes beyond solar system • Did you know fact about NASA using engineering design process • Did you know fact about NASA history • Did you know fact about NASA spacecraft telemetry	Engineering, *Worlds Apart*: Engineering Notebook, pages 10, 14, 16, 17, 22
• Global map of Mars using Viking color data • Reference to Mars Science Laboratory rover Curiosity, 2012 • Reference to HiRISE • Reference to Mars 2020 rover • Reference to High Resolution Imaging Science Experiment (HiRISE) • Reference to Context Camera (CTX) • Table summarizing data from NASA missions and remote sensing instruments: Viking, CTX, HiRISE, MOLA, CRISM • History of visible light images: Viking, CTX, MRO, HiRISE and LiDAR images Mars Orbiter Laser Altimeter (MOLA), Mars Global Surveyor (MGS) • History of infrared light images: CRISM	Science, *Remote Sensing of Mars*, Educator Background, pages 11–15; also in Science Notebook, page 3

Specific NASA datasets, spacecraft (ISS), partners (JPL) and/or missions	Where found/incorporated in unit (Engineering/Science; activity number)
• Link to NASA Mars page • Link to NASA Mars for educators • Link to NASA MER homepage • NASA SMD planetary science questions are introduced to youth • Educators guide youth to explore Viking data • Educators guide youth to explore CTX data • Educators guide youth to explore HiRISE data • Educators guide youth to compare Earth landforms and Mars landforms using images from Landsat/USGS; NASA/METI/AIST/Japan • Space Systems, and U.S./Japan ASTER • Science Team • NASA/JPL-Caltech, Arizona State University; NASA/JPL-Caltech, University of Arizona; NASA/JPL-Caltech, MSSS	Science, Activity 1, pages 23–25
Educators guide youth to explore Viking, CTX, HiRISE, MOLA data	Science, Activity 2, page 29
Educators guide youth to explore Viking, CTX, HiRISE, MOLA, CRISM data	Science, Activity 3, page 35
• Gale Crater Viking image • Iani Chaos Viking image • Jezero Crater Viking image • Nili Fossae Viking image • Gale Crater CTX image • Gale Crater HiRISE image • Iani Chaos CTX image • Iani Chaos HiRISE image • Jezero Crater CTX image • Jezero Crater HiRISE image • Nili Fossae CTX image • Nili Fossae HiRISE image • Gale Crater MOLA topography • Iani Chaos: MOLA Topography • Jezero Crater: MOLA Topography • Nili Fossae: MOLA Topography • Gale Crater: CRISM Data • Iani Chaos: CRISM Data • Jezero Crater: CRISM Data • Nili Fossae: CRISM Data	Science, Data Packet, pages 2–23

Specific NASA datasets, spacecraft (ISS), partners (JPL) and/or missions	Where found/incorporated in unit (Engineering/Science; activity number)
• 4 links to NASA eclipse videos: careers, women in STEM • 2 links to NASA Careers • 5 links to NASA.gov lesson materials and content • 1 link to NASA Earth observatory • Link to https://mars.nasa.gov/imagine/students/ • Link to: https://vestatrek.jpl.nasa.gov/vesta/ • Link to https://lunarscience.nasa.gov/wp-content/uploads/LSF13P/LMMP_nlsf2013.pdf • Link to http://www.lmmp.nasa.gov • Link to https://www.jpl.nasa.gov/edu/teach/activity/space-school-musical/ • Link to 33 Mars mission websites • YouTube playlist of 3 cool NASA videos: ISS, Curiosity 7 minutes of terror, Milestone test of Artemis	https://planets-stem.org/remote-sensing/

Scientific and technical personnel	How incorporated into unit development/unit content
Tracy Drain, NASA JPL Ingrid Daubar, NASA JPL	Special Report video interviewee
Ryan Anderson, USGS Astrogeology Greg Vaughan, USGS Astrogeology Elise Rumpf, USGS Astrogeology Lori Pigue, USGS Astrogeology Moses Milazzo, USGS Astrogeology	Author of science guides, reviewer of engineering guides

Appendix J: Implementation Data

Table J1. Amount of time educators spent on planning and preparation for the units

	Remote Sensing					Water in Extreme Environments					Total				
	N	Mean	*SD*	Min	Max	*N*	Mean	*SD*	Min	Max	*N*	Mean	*SD*	Min	Max
Engineering Materials	8	37.50	23.30	15	90	4	27.50	5.00	20	30	12	34.17	19.40	15	90
Science Materials	6	36.67	30.61	5	90	4	28.75	14.36	10	45	10	33.50	24.61	5	90

Table J2. Educator average ratings of the difficulty to adapt materials by unit

	Remote Sensing			Water in Extreme Environments		
	N	Mean	*SD*	*N*	Mean	*SD*
How difficult was it to adapt the materials to your teaching setting?	9	4.00	0.87	4	4.00	0.82

Table J3. Educator average ratings of the quality of the materials by unit

	Remote Sensing			Water in Extreme Environments		
	N	Mean	*SD*	*N*	Mean	*SD*
The background information was useful to understanding how to use the materials	9	4.11	1.36	4	4.25	0.50
The layout of the materials was well organized	9	3.89	1.27	4	4.00	0.00
The procedures were easy to follow	9	3.67	1.41	4	4.25	0.50
Alignment with standards enhanced the materials' utility	9	3.56	1.24	4	4.25	0.50
The Engineering Showcase was useful to understand the knowledge and skills learners gained from using the materials	9	3.89	1.27	4	4.00	0.82
The materials and activities were appropriate for meeting the needs of diverse learners	9	3.89	1.36	4	4.00	0.00
The materials were culturally appropriate for my learners	9	3.67	1.41	4	4.00	0.00
The activities were developmentally appropriate for my learners	9	3.44	1.51	4	4.00	0.00
The procedures in the instructional guides were clear	9	3.67	1.22	4	4.00	0.00
The instructional design promoted inquiry-based, hands-on learning	9	4.00	1.22	4	4.25	0.50
The materials made guiding and facilitating learning easy	9	4.00	1.22	4	4.00	0.00
Overall, the materials are of high quality	9	3.89	1.36	4	4.00	0.00
Overall, the materials are very useful	9	4.22	1.30	4	4.00	0.00

Table J4. Percentage of educators who used the educator resources for the *Remote Sensing* unit (*n* = 9)

	n	%
Learning Progressions	2	22%
Back Pocket Activity Essentials: Engineering	4	44%
Back Pocket Activity Essentials: Science	2	22%
Educator Content Videos: Intro to Remote Sensing	7	78%
How-To Video for Educators: How to Build a Periscope	7	78%
Remote Sensing FAQs	4	44%
STEM Careers	3	33%
Extension Activities	2	22%
Planetary Science Content	2	22%
Simulations/Interactions	4	44%
NASA Missions	5	56%
Arts Connections	3	33%
Curiosity Seven Minutes of Terror	0	0%

Table J5. Percentage of educators who used the educator resources for the *Water in Extreme Environments* unit (*n* = 4)

	n	%
Vocabulary	0	0%
Science snippets (video): Earth's Water Availability, Accessibility, and Usability	3	75%
Science snippets (video): Water Phases and Reservoirs	2	50%
Science snippets (video): Properties of Water	3	75%
Science snippets (video): The Water Cycle	1	25%
Science snippets (video): Water Reuse in Extreme Environments: Human Technology	2	50%
Science snippets (video): Water in the Solar System	3	75%
Science snippets (video): Water and Habitability	2	50%
Engineering Context-Setting Video for Youth: Engineering Everywhere Special Report: Water Reuse	3	75%
Water in Extreme Environments Pocket Activity Essentials: Engineering	2	50%
Water in Extreme Environments Back Pocket Activity Essentials: Science	2	50%
Educator How-to Video: How to Test the Waters: Part 1	2	50%
Educator How-to Video: How to Test the Waters: Part 2	2	50%
Cool NASA videos: Recycling Water on the Space Station	2	50%
Water in Extreme Environments FAQs	0	0%
Unit At A Glance	3	75%
Learning Progressions	2	50%
Back Pocket Activity Essentials	1	25%
Tips for Interactivity	1	25%
Developing 21st Century Skills	2	50%
STEM Careers	1	25%
Educator Conferences	0	0%
Extension Activities	2	50%
Planetary Science Content	0	0%
Simulations/Interactives	1	25%
NASA Missions	2	50%

Appendix K: PLANETS Youth EIA Results

This section shows the EIA survey results, including the percentage of missing data, descriptive data, and the results for paired samples *t*-tests. Results are shown aggregated across programs and disaggregated by program for the pilot tests and field tests.[12] Additionally, this section shows educators' perceptions of their youths' learning and engagement.

Pilot Tests

Table K1. EIA missing data from the pilot tests

Subscale	*n*	Total Missing	% Missing
Aspirations	777	54	6%
Enjoyment	784	47	6%
School	774	57	7%
Value to Me	805	26	3%
Value to Society	764	67	8%

Table K2. EIA descriptive data and paired samples *t*-test for *Worlds Apart*, *Testing the Waters*, and *In Good Hands* pilot test scale means, combined

	Pretest			Posttest			Paired Samples *t*-Test			
	n	Mean	*SD*	*n*	Mean	*SD*	Mean Difference	*t*	*df*	Sig. (2-tailed)
Aspirations Scale	777	8.82	4.05	777	11.82	3.65	3.00	23.39	776	<.001
Enjoyment Scale	784	9.24	3.97	784	12.88	3.13	3.64	26.75	783	<.001
School Scale	774	10.34	3.58	774	13.57	2.68	3.23	25.66	773	<.001
Value to Me Scale	805	4.77	2.11	805	6.58	1.66	1.80	26.67	804	<.001
Value to Society Scale	764	12.72	4.36	764	16.46	3.48	3.74	25.68	763	<.001

[12] Researchers calculated the EIA survey results for the pilot test by standardizing the scale means. Evaluators did not standardize the scale means when calculating the EIA survey results for the field test.

Table K3. EIA descriptive data and paired samples *t*-test for pilot test scale means, disaggregated by program

	Pretest			Posttest			Paired Samples *t*-Test			
	n	Mean	*SD*	*n*	Mean	*SD*	Mean Difference	*t*	*df*	Sig. (2-tailed)
					Worlds Apart					
Aspirations Scale	284	8.87	4.07	284	11.79	3.53	2.92	13.29	283	<.001
Enjoyment Scale	287	9.38	3.95	287	12.70	3.14	3.32	14.72	286	<.001
School Scale	281	10.30	3.60	281	13.33	2.73	3.03	14.81	280	<.001
Value to Me Scale	292	4.90	2.12	292	6.55	1.62	1.65	15.01	291	<.001
Value to Society Scale	280	12.54	4.47	280	16.19	3.64	3.66	16.61	279	<.001
					In Good Hands					
Aspirations Scale	223	8.84	4.07	223	11.88	3.82	3.04	12.81	222	<.001
Enjoyment Scale	223	9.13	4.11	223	13.00	3.33	3.87	14.70	222	<.001
School Scale	220	10.24	3.79	220	13.70	2.87	3.45	14.19	219	<.001
Value to Me Scale	231	4.75	2.21	231	6.51	1.82	1.76	13.75	230	<.001
Value to Society Scale	222	12.55	4.43	222	16.57	3.48	4.02	13.48	221	<.001
					Testing the Waters					
Aspirations Scale	270	8.76	4.03	270	11.81	3.65	3.05	14.42	269	<.001
Enjoyment Scale	274	9.18	3.89	274	12.97	2.96	3.79	16.99	273	<.001
School Scale	273	10.47	3.40	273	13.71	2.46	3.24	15.42	272	<.001
Value to Me Scale	282	4.67	2.00	282	6.65	1.58	1.99	17.40	281	<.001
Value to Society Scale	262	13.06	4.18	262	16.65	3.28	3.58	14.51	261	<.001

Field Tests

Table K4. EIA missing data from the field test analysis sample (n = 163)

Subscale	Total Missing	% Missing
Aspirations	13	8%
Enjoyment	9	6%
School	13	8%
Value to Me	4	2%
Value to Society	11	7%

Table K5. EIA descriptive data and paired samples *t*-test for *Worlds Apart* and *Testing the Waters* field tests scale means, combined

	Pretest			Posttest			Paired Samples *t*-Test			
	n	Mean	*SD*	*n*	Mean	*SD*	Mean Difference	*t*	*df*	Sig. (2-tailed)
Aspirations Scale	150	2.07	1.15	150	2.57	1.11	0.51	-7.93	149	.00
Enjoyment Scale	154	2.33	1.03	154	2.92	0.99	0.58	-8.23	153	.00
School Scale	150	2.69	0.90	150	3.22	0.82	0.53	-7.77	149	.00
Value to Me Scale	159	2.32	1.07	159	3.05	0.98	0.73	-9.16	158	.00
Value to Society Scale	152	2.47	0.91	152	3.00	0.86	0.53	-8.23	151	.00

Table K6. EIA descriptive data and paired samples *t*-test for the field tests scale means, disaggregated by program

	Pretest			Posttest			Paired Samples *t*-Test			
	n	Mean	*SD*	*n*	Mean	*SD*	Mean Difference	*t*	*df*	Sig. (2-tailed)
					Worlds Apart					
Aspirations Scale	83	2.30	1.16	83	2.68	1.13	0.38	-4.96	82	.00
Enjoyment Scale	86	2.58	0.99	86	2.95	1.05	0.38	-4.57	85	.00
School Scale	85	2.84	0.89	85	3.22	0.87	0.38	-4.31	84	.00
Value to Me Scale	89	2.51	1.07	89	3.11	1.03	0.60	-5.56	88	.00
Value to Society Scale	87	2.67	0.93	87	3.02	0.95	0.35	-4.23	86	.00
					Testing the Waters					
Aspirations Scale	67	1.78	1.08	67	2.44	1.08	0.66	-6.34	66	.00
Enjoyment Scale	68	2.03	1.01	68	2.87	0.91	0.84	-7.34	67	.00
School Scale	65	2.50	0.87	65	3.23	0.75	0.73	-7.06	64	.00
Value to Me Scale	70	2.09	1.02	70	2.99	0.92	0.89	-7.73	69	.00
Value to Society Scale	65	2.20	0.83	65	2.96	0.74	0.77	-8.15	64	.00

Table K7. EIA descriptive data by item for the field tests, disaggregated by program

	Worlds Apart						*Testing the waters*						Total					
	Pretest			Posttest			Pretest			Posttest			Pretest			Posttest		
	N	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	SD
I enjoy studying engineering	91	2.60	1.24	90	3.06	1.11	71	2.00	1.22	71	2.94	1.12	162	2.34	1.26	161	3.01	1.11

	Worlds Apart						Testing the waters						Total					
	Pretest			Posttest			Pretest			Posttest			Pretest			Posttest		
	N	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	SD
I would like to work with other engineers to solve engineering problems	90	2.58	1.22	91	2.80	1.36	71	2.01	1.27	71	2.75	1.22	161	2.33	1.27	162	2.78	1.29
We learn about interesting things when we do engineering	91	2.90	1.12	91	3.15	1.06	69	2.46	1.16	70	3.20	0.99	160	2.71	1.15	161	3.17	1.03
It is important for me to understand engineering	90	2.47	1.29	90	3.10	1.22	71	2.10	1.23	70	2.97	1.06	161	2.30	1.27	160	3.04	1.15
Engineering is fun	91	2.70	1.30	92	3.08	1.27	71	2.17	1.29	71	3.08	0.98	162	2.47	1.32	163	3.08	1.15
When we do engineering, we use a lot of interesting materials and tools	92	2.85	1.27	91	3.25	1.10	71	2.45	1.14	71	3.28	0.97	163	2.67	1.23	162	3.27	1.04
Engineering helps me to understand today's world	92	2.51	1.18	92	3.05	1.15	71	2.10	1.16	71	3.01	1.02	163	2.33	1.19	163	3.04	1.09
It is important to understand engineering in order to get a good job	92	2.62	1.27	92	2.93	1.24	70	2.14	1.20	70	2.80	1.07	162	2.41	1.26	162	2.88	1.17
I am interested when we do engineering	90	2.71	1.33	90	2.98	1.26	69	2.04	1.31	69	2.99	1.18	159	2.42	1.36	159	2.98	1.22
Engineers help make people's lives better	92	2.64	1.25	92	2.95	1.27	70	2.29	1.09	69	3.09	0.98	162	2.49	1.20	161	3.01	1.15
I would enjoy being an engineer when I grow up	91	1.91	1.39	91	2.15	1.44	70	1.46	1.36	69	1.81	1.45	161	1.71	1.39	160	2.01	1.45
Engineering is useful in helping to solve the problems of everyday life	92	2.72	1.25	90	3.10	1.25	69	2.39	1.02	70	3.07	0.91	161	2.58	1.17	160	3.09	1.11

	Worlds Apart						Testing the waters						Total					
	Pretest			Posttest			Pretest			Posttest			Pretest			Posttest		
	N	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	SD
We learn about important things when we do engineering	91	2.73	1.27	90	3.34	0.97	70	2.47	1.21	68	3.22	0.94	161	2.61	1.25	158	3.29	0.96
Engineering is easy for me	91	2.05	1.33	92	2.47	1.34	70	1.81	1.25	69	2.33	1.34	161	1.95	1.30	161	2.41	1.33
Engineering is really important for my country	90	2.81	1.24	91	3.16	1.10	69	2.38	1.09	68	3.10	0.88	159	2.62	1.19	159	3.14	1.01
I try hard to do well in engineering	91	2.71	1.26	90	3.13	1.11	69	2.48	1.22	69	3.13	1.03	160	2.61	1.24	159	3.13	1.07
I would like to learn more about engineering	89	2.57	1.45	89	2.88	1.35	68	1.84	1.43	69	2.52	1.38	157	2.25	1.48	158	2.72	1.37
I know what engineers do for their jobs	91	2.46	1.36	92	2.87	1.25	68	1.87	1.41	69	2.72	1.20	159	2.21	1.41	161	2.81	1.23
I really want to learn engineering	91	2.21	1.52	91	2.76	1.34	69	1.83	1.43	69	2.61	1.27	160	2.04	1.49	160	2.69	1.31

Table K8. Educator average ratings of their students' learning and engagement in the field tests

	Remote Sensing			*Water in Extreme Environments*		
	N	Mean	*SD*	*N*	Mean	*SD*
My learners were more interested in science and engineering as a result of using these materials	9	3.44	1.33	4	4.00	0.00
My learners were engaged in the activities	9	3.67	1.22	4	4.25	0.50
My learners learned about careers in science and engineering from using the materials	9	3.89	1.17	4	4.00	0.82
My learners gained a deeper understanding of the engineering design process from the materials	9	3.89	1.27	4	4.25	0.50
My learners gained a deeper understanding of the topics from participating	9	3.56	1.24	3	4.00	0.00

Appendix L: Impact of Educator Resources

Eight of the 11 educators who participated in the fall 2019 field test and all four educators who participated in the fall 2020 field test completed a knowledge and skills survey, prepared by Magnolia Consulting, after using the curriculum. Evaluators present this data descriptively in the following tables.

Table L1. Educators reported on their average STEM teaching skills before and as a result of teaching the PLANETS unit

	Remote Sensing						*Water in Extreme Environments*					
	Before teaching…			As a result of teaching…			Before teaching…			As a result of teaching…		
	N	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*
Setting science, technology, engineering and mathematics (STEM) learning in a real-world context	8	3.25	0.71	7	4.14	0.69	4	4.00	0.82	4	4.25	0.96
Demonstrating how engineers help people and society solve problems	8	3.00	1.07	8	4.38	0.52	4	3.50	0.58	4	4.25	0.50
Building learners' awareness of STEM careers	8	3.25	0.89	8	4.25	0.71	4	4.25	0.50	4	4.50	0.58
Building learners' awareness of the diversity of individuals involved in STEM careers	8	3.25	1.04	8	4.13	0.83	4	4.00	0.82	4	4.25	0.96
Presenting design challenges that are authentic to engineering practice in the real world	8	2.63	0.92	8	3.88	0.64	4	3.50	1.00	4	4.50	0.58
Providing learners with open-ended challenges	8	3.25	0.46	8	4.25	0.46	4	4.00	0.82	4	4.50	0.58
Helping learners understand the value of "failure" in learning and improving engineering designs	8	3.38	0.74	8	4.13	0.64	4	4.00	0.82	4	4.25	0.96
Cultivating team work and collaboration among learners	8	3.75	0.89	8	4.25	0.46	4	4.00	0.00	4	4.25	0.96
Modeling and making explicit practices of engineering	8	3.25	1.28	8	4.25	0.71	4	3.50	0.58	4	4.50	0.58
Providing activities and lessons that are flexible to the needs and abilities of learners	8	3.50	0.53	8	4.13	0.35	4	4.25	0.50	4	4.25	0.96
Cultivating a learning environment in which all learners' ideas are valued	8	3.75	0.46	8	4.13	0.64	4	4.50	0.58	4	4.25	0.96
Fostering learners' sense that they can be scientists and engineers	8	3.63	0.92	8	3.88	0.83	4	4.25	0.50	4	4.50	0.58

Table L2. Educators reported on their average content knowledge before and as a result of teaching the *Remote Sensing* unit

	Before teaching *Remote Sensing*			As a result of teaching *Remote Sensing*		
	N	Mean	*SD*	*N*	Mean	*SD*
How NASA scientists and engineers collect data on remote worlds	8	2.75	0.89	8	4.25	0.89
The types of problems/questions remote sensing can be used to address	8	2.38	0.92	8	4.25	0.71
How mirrors change the way light travels to collect information from a distance	8	2.63	0.74	7	4.43	0.53
How optical filters are used to support remote sensing technologies to understand remote worlds	8	2.38	1.41	8	3.88	0.83
How light is absorbed	8	3.00	0.93	8	4.25	0.71
How scientists use Light Detection And Ranging (LiDAR) to study the shape of remote landforms	8	1.63	0.74	8	4.38	0.74
How scientists map landforms	8	1.75	0.71	7	4.14	0.69
Mars topography/landforms (craters, troughs, flood deposits)	8	2.13	0.64	8	4.25	0.71
Mars climate	8	2.50	0.93	8	4.25	0.71
How NASA data helps further our understanding of remote worlds	8	2.75	1.04	8	4.38	0.74
How NASA determines the safest and most scientifically useful areas for exploration on remote worlds	8	2.13	0.83	8	4.13	0.83

Table L3. Educators' average rating of the extent to which the educator resourses supported their instruction

	Remote Sensing			*Water in Extreme Environments*		
	N	Mean	*SD*	*N*	Mean	*SD*
…preparing to teach the lessons	9	3.56	1.33	4	4.50	0.58
… teaching the lessons with your learners	9	3.33	1.12	4	4.50	0.58

Table L4. Educators reported on their average content knowledge before and as a result of teaching the *Water in Extreme Environments* unit

	Before teaching *Water in Extreme Environments*			As a result of teaching *Water in Extreme Environments*		
	N	Mean	*SD*	*N*	Mean	*SD*
How process engineering is used to create efficient and high-quality products	4	2.50	1.00	4	3.75	0.50
The difference between pure water, greywater, and wastewater	4	3.75	1.26	4	4.75	0.50
The types of data scientist collect to measure water quality	4	4.00	1.41	4	4.00	0.82
The types of tools/instruments used to assess water quality	4	3.75	1.89	4	4.00	0.82

	Before teaching *Water in Extreme Environments*			As a result of teaching *Water in Extreme Environments*		
	N	Mean	*SD*	*N*	Mean	*SD*
How engineers design systems to treat water	4	2.50	0.58	4	3.75	1.26
Where water exists on Earth (reservoirs)	4	4.25	0.96	4	4.25	0.96
How much of Earth's water is accessible and usable	4	3.75	1.50	4	4.25	0.96
Where water exists in the solar system	4	2.75	0.50	4	4.00	0.82
How distance from the Sun affects the amount of water in the solar system	4	2.00	1.15	4	3.75	1.26
How NASA determines the safest and most scientifically useful areas for exploration on remote worlds	4	1.75	0.96	4	3.50	1.29

Table L5. Educators reported on their average engineering content knowledge before and as a result of teaching the PLANETS unit*

	Remote Sensing						*Water in Extreme Environments*					
	Before teaching…			As a result of teaching…			Before teaching…			As a result of teaching…		
	N	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*
The Engineering Design Process	8	2.75	1.16	8	4.13	0.64	4	4.50	0.58	4	4.75	0.50
How engineers communicate their work	8	3.00	1.07	8	4.13	0.64	4	4.25	0.96	4	3.75	1.26

*Combined across units

Table L6. Educator average ratings of the effects of the units on their instruction

	Remote Sensing			*Water in Extreme Environments*		
	N	Mean	*SD*	*N*	Mean	*SD*
I felt comfortable using the materials	9	3.78	1.20	4	4.75	0.50
Using the materials increased my interest in science and engineering	9	3.78	1.39	4	4.50	0.58
I like teaching science and engineering more as a result of using these materials	9	3.67	1.32	4	4.50	0.58
Using these materials gave me a better understanding of how to facilitate student-centered, hands-on learning processes with my learners	9	3.89	1.27	4	4.25	0.96
Using these materials improved my understanding of how to tie science and engineering learning to real-life contexts	9	3.89	1.27	4	4.25	0.96
Using the materials enhanced my capacity to teach science and engineering	9	3.89	1.27	4	4.50	0.58
I would recommend these materials to a colleague	9	4.22	1.30	4	4.50	0.58
I would use these materials again	9	4.11	1.36	4	4.75	0.50

Appendix M: PLANETS Dissemination

Publications

Bloom, N. E., & Clark, J. (2017). *Assessing the content and instructional needs of out-of-school time (OST) educators for teaching integrated science and engineering curricula* [Unpublished report]. Center for Science Teaching and Learning, Northern Arizona University.

Bloom, N., Roberts, E., Clark, J., Rubino-Hare, L., Cunningham, C., & Archer, H. (2019, June). How educators implement engineering curricula in OST settings [Conference paper]. *Proceedings of the 2019 American Society for Engineering Education Annual Conference, Tampa, FL.* https://peer.asee.org/how-educators-implement-engineering-curricula-in-ost-settings-fundamental.pdf

Clark, J., Bloom, N., Rubino-Hare, L., Barnes, C., & Ryan, S. (2020). *Designing professional development resources to meet the needs of OST stem educators* [In review].

Engineering is Elementary Team. (2017a). *Testing the Waters: Engineering a Water Reuse Process*. Museum of Science. https://www.eie.org/engineering-everywhere/curriculum-units/testing-waters

Engineering is Elementary Team. (2017b). *Worlds Apart: Engineering Remote Sensing Devices*. Museum of Science. https://www.eie.org/engineering-everywhere/curriculum-units/worlds-apart

Engineering is Elementary Team. (2019). *In Good Hands: Engineering Space Gloves*. Museum of Science. http://d7.eie.org/engineering-adventures/curriculum-units/good-hands

PLANETS. (2019). *Remote Sensing of Mars: Planetary science for out-of-school-time grades 6–8*. https://www.planets-stem.org

PLANETS. (2020a). *Space Hazards: Planetary science for out-of-school-time grades 3–5*. https://www.planets-stem.org

PLANETS. (2020b). *Water in the Solar System: Planetary science for out-of-school-time grades 6–8.* https://www.planets-stem.org

San Antonio-Tunis, C., Clark, J., & Cunningham, C. (2019, June 16–19). *Engineering interest and attitude development in out-of-school time* [Conference paper]. American Society for Engineering Education 126th Annual Conference and Exposition, Tampa, FL.

Presentations

Barlow, N. G. (2016, September). *PLANETS: Space science curricular materials for out-of-school-time programs* [Conference session]. Western Region Space Grant Meeting, Bend, OR.

Bloom, N. E., & Clark, J. (2017, December). *Assessing the content and instructional needs of out-of-school time (OST) educators for teaching integrated science and engineering curricula* [Conference session]. American Geophysical Union Fall Meeting, New Orleans, LA.

Bloom, N. E., & Clark, J. (2019, October). *Supports for out-of-school time (OST) STEM education* [Conference submission]. Navajo Nation Annual Research Conference, Window Rock, AZ.

Bloom, N. E., Rubino-Hare, L., Roberts, E., & Clark, J. (2019, December). *Identifying supports for educators facilitating a planetary science and engineering out-of-school time program* [Interactive poster presentation]. Annual meeting of American Geophysical Union, San Francisco, CA. https://agu2019fallmeeting-agu.ipostersessions.com/Default.aspx?s=AD-AD-E7-F8-9F-33-C1-13-4E-A2-85-DB-EB-C1-DF-76

Clark, J. (2018, March). *Out-of-school time STEM is out of this world!* [Conference session]. National Science Teachers Association (NSTA) Atlanta National Conference, Atlanta, GA.

Clark, J. & Bloom, N. E. (2016, December). *What do informal educators need to be successful in teaching planetary science and engineering? Results from the PLANETS out-of-school time educator needs assessment* [Conference session]. Annual meeting of American Geophysical Union, San Francisco, CA. https://agu.confex.com/agu/fm16/meetingapp.cgi/Paper/118916

Clark, J. & Bloom, N. (2017, December). *Data driven professional development design for out-of-school time educators using planetary science and engineering educational materials (NASA NNX16AC53A)*

[Conference session]. American Geophysical Union Fall Meeting, New Orleans, LA. https://agu.confex.com/agu/fm17/meetingapp.cgi/Paper/218800

Clark, J., Hamlin, A., & Rubino-Hare, L. (2020). *Supporting youth development through STEM curriculum* [Conference session]. National AfterSchool Association Annual Convention, Washington, DC.

Clark, J., & Rubino-Hare, L. (2018). *Planetary learning that advances the nexus between engineering, technology, and science (PLANETS): Taking out of school time engineering education to new heights* [Conference session]. Engineering is Elementary Symposium, Boston, MA.

Clark, J. & Rubino-Hare, L. (2020). *PLANETS out-of-school time resources for grades 3-5* [Conference session]. Solar System Exploration Public Engagement Institute, Houston, TX.

Clark, J., Rubino-Hare, L., Bloom, N., & San Antonio-Tunis, C. (2020). *Core values and principles guiding STEM in out-of-school* [Conference paper]. American Geophysical Union Annual Conference.

Haden, C. (2017, November). *Evaluating partnerships & networks: using mixed-methods evaluation to keep STEM collaborations on track* [Conference session]. American Evaluation Association, Washington, DC.

Kesler, K., & Rumpf, E. (2019a, May). *Inspiration station: free STEM curriculum that is out-of-this world* [Conference session]. Best Out Of School Time Conference, Palm Springs, CA.

Kesler, K., & Rumpf, E. (2019b, May). *Camp Inspire: Free STEM curriculum that is out-of-this world* [Conference session]. Best Out Of School Time Conference, Palm Springs, CA.

Milazzo, M., Anderson, R. B., Edgar, L. A., Gaither, T., & Vaughan, R. G. (2017, December). *A subject matter expert view of curriculum development* [Conference session]. American Geophysical Union Fall Meeting, New Orleans, LA. https://agu.confex.com/agu/fm17/meetingapp.cgi/Paper/280791

Rubino-Hare, L., & Clark, J. (2017). *Integrated engineering and planetary science activities for out-of-school time programs* [Conference session]. Space Exploration Educator Conference, Houston, TX.

Rubino-Hare, L., & Clark, J. (2019). *Remote Sensing of Mars* [Conference session]. Space Exploration Educator Conference, Houston, TX.

Rubino-Hare, L., & Clark, J. (2020). *PLANETS out-of-school time for grades 3-5: Engineering gloves to protect from space hazards* [Conference session]. Space Exploration Educator Conference, Houston, TX.

Rubino-Hare, L., & Hamlin, A. (2019). *In good hands: Designing space gloves to protect astronauts from space hazards* [Conference session]. Annual meeting of Arizona Center for Afterschool Excellence, Phoenix, AZ.

Rumpf, M. E., Clark, J., Anderson, R. B., Hamlin, A., Pique, L., San Antonio-Tunis, C., Stokes, R., and Vaughan, R. G. (2020). *A cooperative pivot and at home STEM education by a scientist-educator partnership* [Conference paper]. American Geophysical Union Annual Conference.

Rumpf, M. E., Clark, J., Anderson, R. B., Vaughan, R. G., Rubino-Hare, L., Powers, J., Ryan, S., Glaspie, L. M., & San Antonio-Tunis, C. (2019, December). *Space Hazards! A PLANETS Science Series activity for out of school time* [Conference session]. Annual meeting of the American Geophysical Union, San Francisco, CA. https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/507676

Rumpf, M. E., Vaughan, R. G., Anderson, R., Edgar, L., Gaither, T., Milazzo, M., Rubino-Hare, L., Clark, J., Ryan, S., & Sokol, K. (2018, December). *Planetary cards: An interactive card game for learning about water in the solar system* [Conference session]. American Geophysical Union Fall Meeting, Washington, DC. https://agu.confex.com/agu/fm18/prelim.cgi/Paper/452316

Rumpf, M. E., Vaughan, R. G., Anderson, R., Edgar, L., Gaither, T., Milazzo, M., Rubino-Hare, L., Clark, J., Ryan, S., & Sokol, K. (2019, February). *Planetary cards: A fun and interactive card game for learning about water in the solar system* [Conference session]. Women in Space Conference, Scottsdale, AZ.

Ryan, S., & Rubino-Hare, L. (2016, October). *Inspire a bright future with engineering & planetary science* [Conference session]. Annual meeting of Arizona Center for Afterschool Excellence, Phoenix, AZ.

Ryan, S., & Rubino-Hare, L. (2017). *STEM changes everything* [Conference session]. Annual meeting of National Summer Learning Association, Phoenix, AZ.

Posters

Anderson, R. B., Gaither, T., Edgar, L., Milazzo, M. P., Vaughan, R. G., Rubino-Hare, L., Clark, J. G., & Ryan, S. (2017). *Remote sensing mars landing sites: An out-of-school time planetary science education activity for middle school students* [Poster presentation]. American Geophysical Union Fall Meeting, New Orleans, LA.

Anderson, R. B., Rumpf, M. E., Clark, J., Vaughan, R. G., Pigue, L. M., Rubino-Hare, L., Ryan, S., Powers, J. M., San Antonio-Tunis, C., Bloom, N., & Haden, C. (2020). *Out-of-school time engineering and planetary science units developed by the PLANETS project* [Poster presentation]. Lunar and Planetary Science Conference, Houston, TX. https://www.hou.usra.edu/meetings/lpsc2020/pdf/2177.pdf

Barlow, N. G., & Clark, J. (2017, October). *Planetary science educational materials for out-of-school-time educators* [Poster presentation]. Division for Planetary Sciences meeting, Provo, UT.

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Clark, J., Bloom, N. E., & Henderson, D. (2017, March). *After school STEM is out of this world!* [Poster presentation]. National Afterschool Association, Dallas, TX.

Clark, J., Rubino-Hare, L., & Ryan, S. (2018, December). *Engagement of out-of-school time educators in the design of on-line professional development (NASA NNX16AC53A)* [Poster presentation]. American Geophysical Union Fall Meeting, Washington, DC.

Edgar, L. A., Anderson, R. B., Gaither, T. A., Milazzo, M. P., Vaughan, R. G., Rubino-Hare, L., Clark, J., & Ryan, S. (2017, December). *Water in the solar system: the development of science education curriculum focused on planetary exploration, Abstract ED53H-0226* [Poster presentation]. American Geophysical Union Fall Meeting, New Orleans, LA.

Haden, C., & Clark, J. (2019, December). *Out of this world: evaluation of a remote sensing curriculum for out-of-school time learners* [Poster presentation]. Annual meeting of the American Geophysical Union, San Francisco, CA.

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Milazzo, M. P., Anderson, R. B., Edgar, L., Gaither, T., & Vaughan, R. G. (2017, March). *PLANETS: Planetary learning that advances the nexus of engineering, technology, and science: A subject matter expert view of curriculum development* [Poster presentation]. 48th Lunar and Planetary Science Conference, The Woodlands, TX.

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Milazzo, M. P., Clark, J., Anderson, R. B., Gaither, T., & Vaughan, R. G. (2016, March). *Planetary learning that advances the nexus of engineering, technology, and science* [Poster presentation]. 47th Lunar and Planetary Science Conference, The Woodlands, TX.

Roberts, E., Bloom, N. E., Clark, J., Rubino-Hare, L., Archer, H., San Antonio-Tunis, C., & Lachapelle, C. (2019). *Out-of-school-time educators linking youth funds of knowledge in a middle-school engineering and planetary science curriculum* [Poster presentation]. Annual meeting of National Association of Research in Science Teaching, Baltimore, MD.

Vaughan, R. G., Edgar, L., Rumpf, M. E., Anderson, R., Gaither, T. A., Milazzo, M. P., Rubino-Hare, L., Clark, J., Ryan, S., & Sokol, K. (2018, December). *Water in the solar system: A science education activity focused on planetary exploration* [Poster presentation]. 2018 American Geophysical Union Fall Meeting, Washington, DC.

Vaughan, R. G., Meyer, N., Sokol, K., Nolan B., Anderson, R. B., Edgar, L., Gaither, T., Milazzo, M., & Clark, J. (2017). *Hazards in the solar system: Out-of-school time student activities focused on engineering protective space gloves* [Poster presentation]. American Geophysical Union Fall Meeting, New Orleans, LA.

Convened Sessions

Clark, J., Erickson, K., Young, A., & Mayo, L. (2019, December). *Building STEM learning ecosystems to maximize impact for diverse learners* [Oral and poster sessions]. American Geophysical Union Annual Meeting, San Francisco, CA.

Milazzo, M., Vaughan, R. G., Boonstra, S. K., & Erickson, K. (2016, December). *NASA Science Mission Directorate Science Education: Activation for STEM learning I* [Conference session]. Annual meeting of American Geophysical Union, San Francisco, CA.

Vaughan, R. G., Erickson, K., Milazzo, M., & Boonstra, S. K. (2017, December). *Sharing the story, the science, and the adventure of NASA's scientific explorations* [Oral and poster presentations]. American Geophysical Union Fall Meeting, New Orleans, LA.

Vaughan, R. G., Clark, J., Milazzo, M., & Erickson, K. (2018, December). *Call to action: NASA science and learning collaborations* [Oral and poster presentations]. American Geophysical Union Fall Meeting, Washington, DC.

Workshops

Clark, J., & Ryan, S. (2017, June). *PLANETS curriculum* [Workshop presentation]. Arizona State University Mars Educator Workshop, Tempe, AZ.

Kesler, K., & Rumpf, M. E. (2019, April). *PLANETS: Free STEM curriculum that is out-of-this world!* [Conference session]. Best Out Of School Time Conference, Palm Springs, CA.

PLANETS. (2020, February). *Universal design for learning* [Workshop]. CAST – Museum of Science, Boston, MA.

Rubino-Hare, L., & Clark, J. (2019). *Middle school space science workshop, grades 6–8* [Workshop presentation]. Northern Arizona University, Center for Science Teaching and Learning, Flagstaff, AZ.

Rubino-Hare, L., & Hamlin, A. (2019). *In good hands: Designing space gloves to protect astronauts from space hazards* [Conference session]. Annual meeting of Arizona Center for Afterschool Excellence, Phoenix, AZ.

Rubino-Hare, L., Hamlin, A., & Ryan, S. (2020). *How to protect ourselves from hazards on Earth and in space* [Conference session]. Annual meeting of Arizona Center for Afterschool Excellence, Phoenix, AZ.

Ryan, S., & Fitz-Kesler, V. (2017, October). *PLANETS curriculum* [Oral presentation]. Flagstaff's Festival of Science, Flagstaff, AZ.

Ryan, S., & Rubino-Hare, L. (2016, October 22). *PLANETS: Inspire a bright future with engineering and planetary science* [Conference session]. AzCASE Conference, Phoenix, AZ.

Ryan, S., & Rubino-Hare, L. (2016, November 19). *PLANETS: Inspire a bright future with engineering and planetary science* [Oral presentation]. Arizona Science Teachers Association, Phoenix, AZ.

Ryan, S., & Rubino-Hare, L. (2017, October 28). *Testing the waters: engineering and planetary science in OST* [Conference session]. AzCASE Conference, Phoenix, AZ.

Appendix N: PLANETS Activities and Outcomes Aligned to NASA Top-Level Objectives

Table N1. PLANETS activities and outcomes aligned to NASA top-level objectives

PLANETS Objective 1—Model an Interdisciplinary Partnership Aligns to: NASA Top-Level Objective 4: Leverage efforts through partnerships	
Project Activities	Project Outcomes
• Conduct annual partner working sessions. • Conduct monthly partner lead check-ins. • Execute site visits at curriculum, SME, and professional development partners. • Encourage mutual use of formative evaluation research.	• Partners gain increased understanding of the effectiveness of the curricular units and educator resources in addressing student engagement and STEM learning (short term).
PLANETS Objective 2—Develop Nationally Available Curricular Units to Reach Underserved Populations	
Aligns to: NASA Top-Level Objective 1: Enable STEM education in all 50 states NASA Top-Level Objective 2: Improve U.S. scientific literacy NASA Top-Level Objective 3: Advance national education goals	
Project Activities	Project Outcomes
• Develop 3 OST curricular units: 1 for upper elementary and 2 for middle school. • Develop videos, apps, and multimodal notebooks for OST students. • Pilot-test units in a variety of settings, especially with underrepresented populations. • Collect data to inform curricular revisions. • Conduct impact study with students.	• Students show positive attitudes toward and understanding of planetary science, engineering design, and NASA programs (short term). • OST providers implement units in summer and after-school programs (intermediate). • Students engage in targeted engineering and science practices (short term).

PLANETS Objective 3—Create and Test Educator Resources Aligns to: NASA Top-Level Objective 1: Enable STEM education in all 50 states NASA Top-Level Objective 2: Improve U.S. scientific literacy NASA Top-Level Objective 3: Advance national education goals	
Project Activities	Project Outcomes
• Conduct needs assessment with OST providers, especially for underrepresented groups. • Develop professional development videos and other educator resources to support OST providers. • Conduct impact study with OST providers and students.	• OST providers develop increased capacity to integrate planetary sciences and engineering content into OST programs (short-term). • OST providers increase their understanding of planetary sciences and engineering concepts (short term). • OST providers implement units with students in summer and after-school programs (intermediate).

PLANETS Objective 4—Disseminate Curriculum, Educator Resources, and Knowledge on OST STEM Teaching and Learning Aligns to: NASA Top-Level Objective 3: Advance national education goals NASA Top-Level Objective 2: Improve U.S. scientific literacy	
Project Activities	Project Outcomes
• Disseminate curricular materials, educator resources, and knowledge at national and state OST conferences. • Publish all project materials via MOS (eie.org) and NASA assets (e.g., http://nasawavelength.org/).	• OST programs and the general public have access to high-quality curricular materials aligned to NASA educational outcomes (long term). • Project contributes to the body of knowledge on effective approaches to increasing student engagement in STEM (long term).