Designing Professional Development Resources to Meet the Needs of OST STEM Educators

Joëlle Clark, Nena Bloom, Lori Rubino-Hare,
Courtney Barnes, and Sean Ryan

Flexibility, opportunities for exploration, and a focus on 21st century skills make out-of-school time (OST) programs an ideal environment for authentic learning in science, technology, engineering, and mathematics (STEM; Committee on STEM Education, 2013; Noam & Shah, 2014). In addition, because OST programs serve significant populations of young people who are underrepresented in STEM, they may be able to reduce the opportunity gap for these youth and help to enhance youth learning and engagement.

JOËLLE CLARK, MA, MAST, is associate director for the Center for Science Teaching and Learning at Northern Arizona University (NAU). Her interests include informal science learning and anthropology. She is principal investigator for PLANETS, the NASA-funded program described in this article.

NENA BLOOM, EdD, is assistant director for the Center for Science Teaching and Learning at NAU. She is interested in collecting and analyzing data to help programs make evidence-based decisions to improve teaching and learning.

LORI RUBINO-HARE, MEd, is a professional development coordinator/research associate for the Center for Science Teaching and Learning at NAU. She is interested in facilitating educator professional learning that enables reflection and improved practices.

COURTNEY BARNES is a graduate student at the Center for Science Teaching and Learning at NAU. She is interested in how culturally relevant pedagogies can be implemented in out-of-school time settings.

SEAN RYAN is a professional development coordinator/research associate for the Center for Science Teaching and Learning at NAU. He is interested in building resources that promote inquiry-driven STEM learning.

Efforts to design high-quality STEM curricula and educator professional development resources help to increase opportunities for youth to engage in STEM in OST. However, each OST educator has unique professional needs depending on their program. Therefore, a strong STEM curriculum must include professional learning support for OST educators. Few OST educators have formal education training or teacher certifications (National Afterschool Association, 2006). According to the National Afterschool Association's national survey (2006), most workers had little experience or education directly relevant to afterschool programs and received no paid time to pursue training.

Research demonstrates strong connections between OST professional development and benefits realized by program participants (Bowie & Bronte-Tinkew, 2006; Garst et al., 2014; Palmer et al., 2009). Professional development, especially in STEM content, can improve the content knowledge of OST educators and help OST programs meet their goals (Afterschool Alliance, 2011; Allen et al., 2017; Chi et al., 2008; Chun & Harris, 2011; Freeman et al., 2009). As Freeman et al. (2009) point out, "transforming the existing cadre of afterschool instructors into effective facilitators of STEM learning will require significant attention to and investments in staff development" (p. 5). Specialized staff development in STEM should include new strategies and must address the diverse needs of OST educators. Ideally the professional development strategies will provide information, skills, and support precisely when educators need them most.

This article presents one approach to the design and development of professional learning resources for OST educators as they implement a high-quality STEM curriculum. The resources we developed as a team, based on our research into the STEM professional development needs of OST practitioners, constitute a form of self-driven professional learning. The tiered system of professional development resources we developed may guide other OST STEM programs toward providing the professional learning resources OST educators need to facilitate quality instruction.

[W]e noticed substantial curricular negotiation at play in the sites we studied. In implementing the written curriculum, the adults involved had to see to what extent it would work in this time, in this place, with these girls.

The PLANETS Program

The OST STEM professional development resources we designed are part of PLANETS, a NASA-funded OST program for educators and youth in grades 3–8 that provides STEM learning with an emphasis on NASA planetary science and engineering, particularly for underserved audiences. The PLANETS program consists of three curricular units: Remote Sensing (grades 6–8), Water in Extreme Environments (grades 6–8), and Space Hazards (grades 3–5). The units engage teams of youth in the disciplinary practices and processes of scientists and engineers through open-ended activities, as recommended by the National Research Council (2009). Learners analyze scientific data, make and refine design choices, reflect on their learning to solve problems set within a NASA planetary science context, and communicate what they learn with their families in a community showcase. The program also includes professional learning resources, which are available on the PLANETS website.

To find out what other professional development resources OST educators might need, we conducted a national needs assessment and case study research. We then devised a tiered system of educator resources to provide just-in-time support.

The PLANETS curriculum and professional development resources are available free of charge at www.planets-stem.org

Determining the Needs of OST STEM Educators

Before we designed professional development resources, we wanted to find out what kinds of resources OST STEM educators need and what constraints they face. To do so, we first conducted a national needs assessment survey and interviews with OST educators. Then we conducted case study research consisting of observations of OST educators implementing PLANETS activities. The evidence from both studies informed the subsequent development of tiered professional learning resources.

PLANETS National Needs Assessment

The primary goal of the national needs assessment study was to understand the limitations and opportunities for STEM in OST and identify the gaps between the self-identified abilities of OST educators and the abilities that effective OST educators should have (Bloom & Clark, 2017). The needs assessment included a literature review, a national online survey with a convenience sample of 314 OST staff and supervisors, and in-depth interviews with 12 OST supervisors.

The findings of the study indicated that OST professional development should be directly applicable to content being taught. OST educators said that professional development was most useful when they learned about activities they would use immediately with youth participants, expanded their content knowledge, or learned about relevant resources for learners or for program development. Professional development must be accessible to staff in a variety of settings, including in rural locations where opportunities are often scarce and attending face-to-face professional development is costly. Because OST staff have a range of professional preparation and experience as educators, they have varied content and instructional needs. Thus, OST educators indicated that they prefer to customize and self-select their professional development sessions based on their immediate needs. They noted that they are willing to use online or hybrid methods, particularly video (Bloom & Clark, 2017).

When asked how they currently received professional development, almost three-quarters of the OST staff respondents said that they were required to participate in some form of professional development. Most said they participated in less than five hours per year. Time and funding were the biggest barriers. Although staff said they felt confident to teach many important STEM areas, supervisors reported that most staff lacked preparation in these areas and would benefit from STEM professional development. Respondents indicated that, in order to improve STEM programming, they needed curricula, hands-on materials, strategies for engaging youth collaboratively, and complementary resources to extend learning (Bloom & Clark, 2017). Figure 1 shows the learning needs identified by staff and supervisors, including connecting STEM projects to real-world applications, modeling science and engineering practices, and deepening their own science understanding.

Top pedagogical needs identified by respondents included facilitating collaborative groups, obtaining materials, promoting youth development and identity, accessing and providing STEM career information, and engaging families and communities in STEM learning. Respondents said that professional development is most useful when educators learn about activities to use immediately with youth, expand their content knowledge, and learn about relevant resources (Figure 2).

Figure 1. STEM Professional Development Needs Identified by Staff and Supervisors

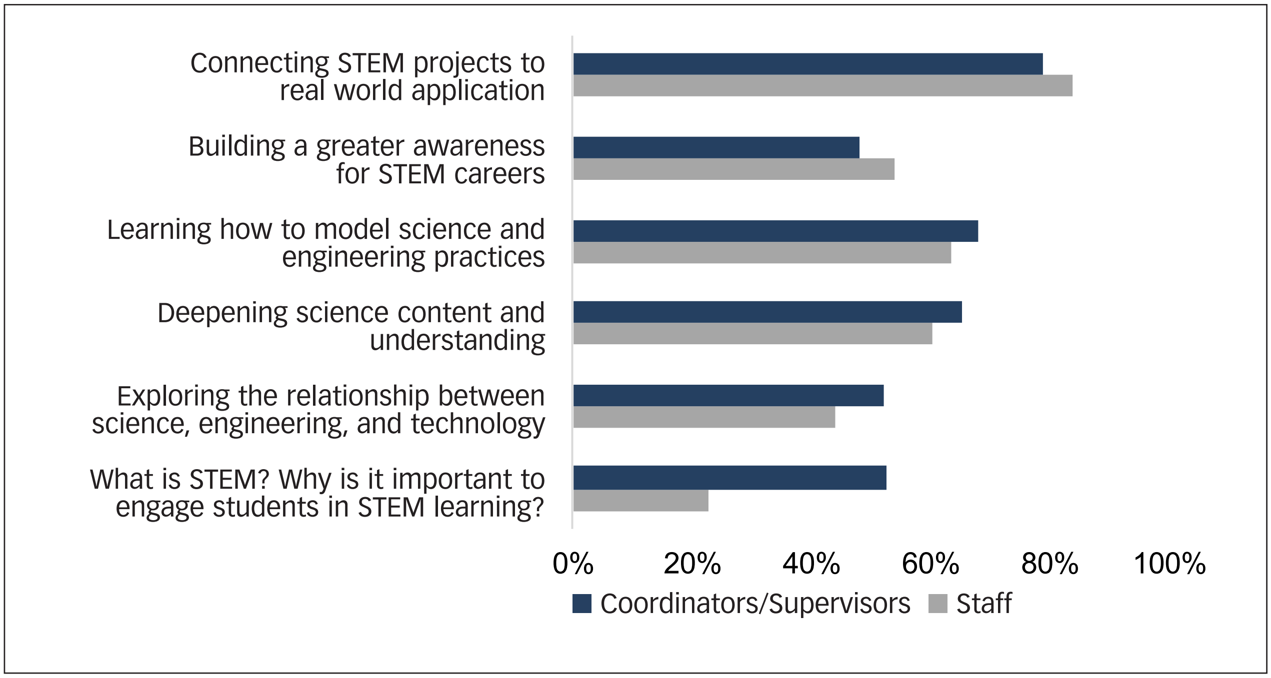
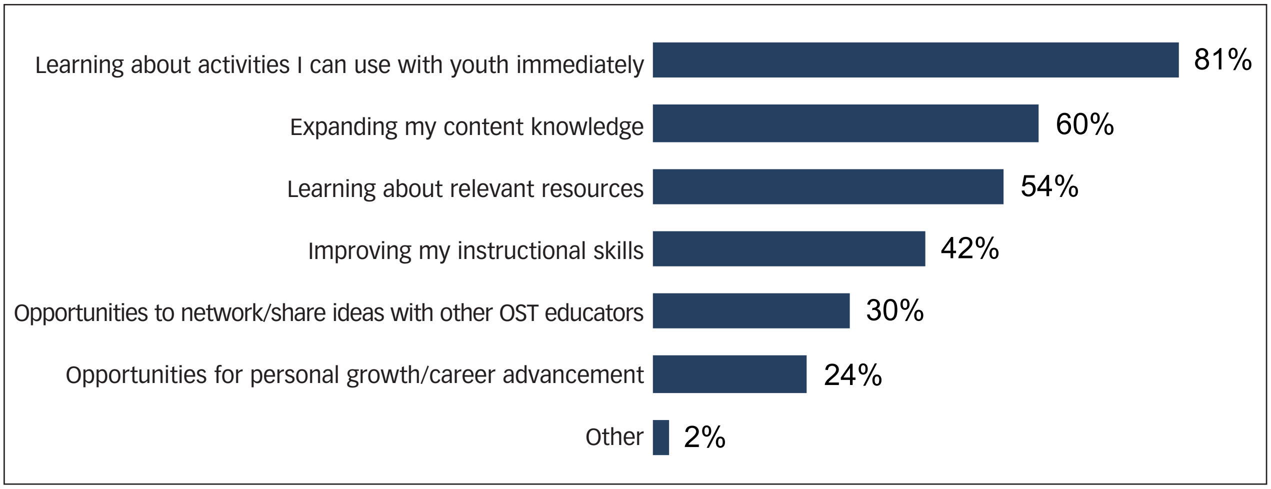


Figure 2. Factors That Make Professional Development Useful



The needs assessment illustrated that OST educators would benefit from professional development that is short, provides opportunities to focus on the STEM content being taught, delivers immediate support for planned activities, and can be accessed easily as needed. Resources for making career and real-world connections, as well as extension activities, were also identified as important for meeting youth development goals.

PLANETS Case Study Research

Another body of evidence that contributed to understanding professional development needs involved systematic observations of OST educators and youth participants during implementation of PLANETS units (Bloom et al., 2019). The purpose of the case study research was to examine how the OST materials affected learners' engineering attitudes and thinking and how the educators supported STEM learning. The study involved four middle grade school OST settings and a total of 52 young people. Two PLANETS units were implemented; each activity was videotaped and later transcribed for analysis. In addition, educators and participants completed surveys and were interviewed. On examining the case study data, we identified three strategies that would enhance OST educators' understanding of STEM content and implementation of STEM practices:

1. Visualizing the overall purpose of the STEM unit and the articulation of activities within the unit
2. Developing knowledge related to the specific STEM content of the unit
3. Supporting specific pedagogical strategies used to enhance STEM learning

Visualizing the purpose of the unit and how its activities contribute is important because STEM activities and ideas build on one another. Youth attendance in OST programs is often inconsistent; OST educators create consistency by reviewing the purpose of activities and their connection with unit goals at every session. For PLANETS, educators must frequently describe how the activities, which involve using science and engineering to solve problems, build on one another. In case study observations, we noted that some educators did not routinely share the purpose of the unit with participants. As a result, some learners did not see the connections among activities. For example, in the Water in Extreme Environments unit, learners collect data on the properties of filter materials in a set of activities. Then they use these data to design a water filtering process to be used in an extreme environment. In our observations, the learners did not always connect the need to test filter materials with the goal of engineering an optimal design for their water filtering process. These learners needed their OST educators to emphasize the learning goals for each activity and how those goals applied to the later engineering challenge. The OST educators in the case study suggested that a detailed unit map would help them guide learners to see the purpose of the individual activities in relation to the whole unit.

The rigorous STEM content in the PLANETS units was outside the typical content knowledge of many educators. Educators are more successful in guiding learners if they have some content knowledge specific to the activity. For example, in the Remote Sensing unit, the planetary science content emphasizes how engineered devices are used to collect data on the topography and mineral content of planetary bodies using technologies such as light detection and ranging (LiDAR) and spectroscopy. In one of the engineering activities, learners use plastic straws to represent how LiDAR beams are used to map the surface of a planet for landing sites. Educators and program participants alike had trouble making the connection between the straws and LiDAR because they did not understand how LiDAR works. Although the educator guide provides written information about this activity, some educators did not have the time to read the information before teaching, as they focused on preparing materials. As a result, we observed educators searching the internet during the program session for background knowledge they could share with learners—often without success. If educators modify activities because they find the content challenging, fidelity of implementation is limited.

Finally, observers indicated that educators might benefit from a deeper understanding of STEM pedagogical strategies, such as the importance of failure in engineering design and the need for closure and reflections following an activity. Many young learners get easily frustrated if their designs do not work the first time or work only partially. Helping educators understand that innovation and problem solving inherently involve an iterative process of testing and improvement will help them support youth development. OST STEM is an opportunity to help develop STEM habits of mind including persistence, collaboration, and problem solving.

Designing Needs-Based STEM Professional Development Resources

The needs assessment and case study suggested several specific ways to supplement existing PLANETS resources to make professional development more effective and support implementation of the curriculum. The PLANETS written curriculum guides provide many types of support: background content; learning cycle processes of engagement, exploration, application, and reflection; engineering design process; materials needed for activities; tips and facilitation strategies for learners in groups; suggested question prompts to guide learners; and additional fun facts to share with participants. What the needs assessment and case study research revealed was that the OST educators needed different types of support at different junctures during implementation of the curriculum. Building on the needs assessment finding that providing a variety of learning resources online is a flexible way to support OST educators, we designed a tiered system of professional learning resources to meet their needs.

To do so, we enlisted OST educators nationally to co-create the resources. We conducted working sessions with OST frontline staff and site leaders to review the findings of the needs research, to examine the PLANETS curriculum, and to brainstorm ideas on how to support OST educators as they implement the curriculum. The working sessions further illuminated the demands and issues faced by OST educators, including lack of time for preparation and competing OST program priorities. The participating OST educators emphasized that professional learning resources must be clear, explicit, short, easy to digest, and designed for the specific unit being taught. Table 1 provides a sample of the types of professional learning resources developed as a result of the co-creation process with OST educators and leaders.

Tier 1: Immediate Needs

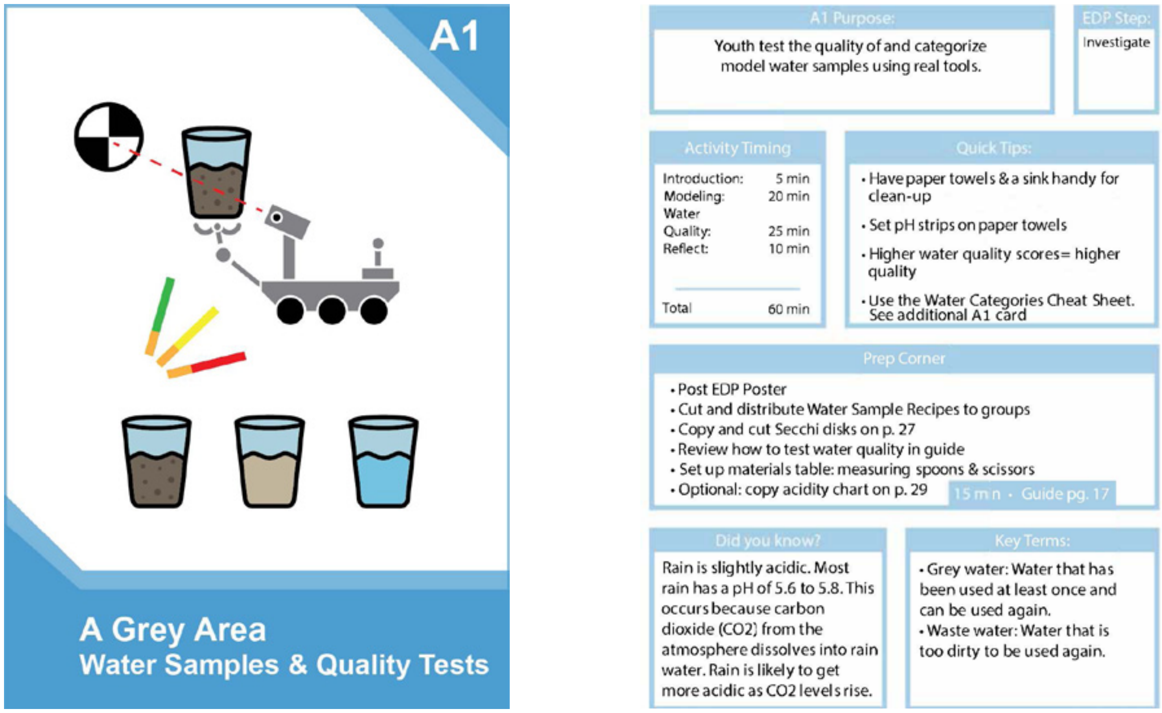
One of the biggest concerns of the OST educators was support in setting up STEM activities, a task that often focuses on the necessary materials. Busy OST educators typically have little time to fully read the curriculum guide and prepare activities before program participants arrive. As they rush through last-minute preparations, they may miss key steps. To mitigate this challenge, we developed the first tier of support, which meets immediate setup needs by providing short how-to videos and "back pocket" activity overviews. The videos demonstrate materials preparation step by step and provide other quick tips on setup and implementation. The back-pocket activity essentials, like the one in Figure 3, provide an overview of each activity at a glance, including the activity purpose, timing, key terms, and preparation reminders. These overviews are available on the PLANETS professional development website and can be viewed on mobile devices or printed.

Another resource we developed to help with immediate activity implementation is unit maps of learning progressions like the one shown in Figure 4. These unit maps visually show the flow of the lessons and the purpose of each so that educators can quickly see where each activity fits into the unit, why the activity occurs at that point in the sequence, and how the activity supports learners to succeed in the final design challenge. The learning progressions are color coded into three types of activities: preparation lessons that introduce background knowledge, common vocabulary, and the

Table 1. The PLANETS Tiered System of Professional Development Supports

Tier of Support	Description	Identified Needs	Sample Resources
1. Immediate needs	Resources to help OST educators get started on facilitating the unit: What do I need to do today? How do I organize the learning? How do I set this activity up?	• Unit overview connecting the purpose of each activity • Activity preparation and materials setup	• Unit maps (PDF) • Learning progressions (PDF) • How-to videos • Quick reference guides for each activity on purpose, preparation, and implementation time (PDF)
2. STEM content and practices	Resources to help educators understand the STEM content: What does this term mean? What do I need to know about this specific planetary science concept to help participants succeed in these activities?	• OST educator background in specific STEM content	• Short, targeted background content videos
3. Pedagogical support	Strategies that help educators support STEM learning and development of STEM habits of mind: How do I get kids to work collaboratively and share their ideas? How can I help them work through the frustrations of a failed design so they are motivated to make improvements? How can I relate this activity to their lives?	• Promotion of STEM habits of mind • Youth development skills • Connections between STEM and real-world relevance	• Explanation of STEM habits of mind (PDF) • Questions to ask during an engineering design process to promote 21st century skills (PDF) • Strategies to reveal the relevance of STEM (PDF)
4. Unit or activity extensions	Extensions of learning to connect youth to STEM careers, NASA missions, and other STEM learning opportunities	• STEM careers • Extended learning opportunities	• Annotated hyperlinks to recommended videos, digital interactive sites, and resources to support STEM careers and family engagement

Figure 3. Sample STEM Activity Back Pocket Essentials



problem to be solved; investigation activities in which program participants gather data to inform final designs or decisions; and culminating activities in which youth communicate final decisions and solutions. Unit maps enable educators to help learners understand the *what, why,* and *how* of each lesson.

Tier 2: STEM Content and Practices

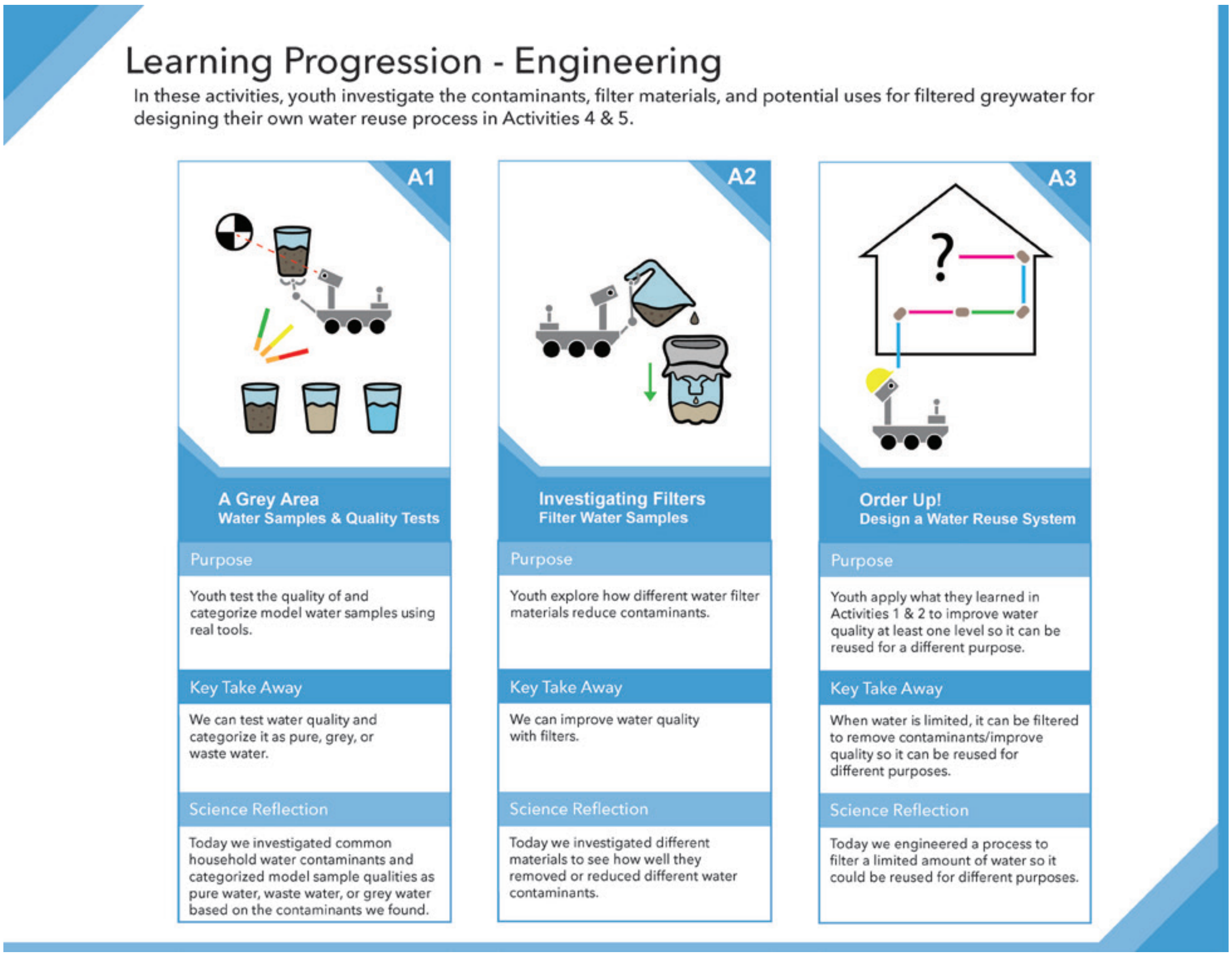
Once OST educators settle into the nuts and bolts of how to prepare activities for learning, they can devote time to the unit's science content and engineering practices. The needs assessment and case study research suggested that OST educators may need support to understand the key science and engineering concepts in the STEM units they are leading. Case study educators identified terms and topics for which they needed succinct summary resources. They suggested that we create an easy way to access the STEM content knowledge related to the concepts and practices of a given unit or activity. The OST educators in the co-creation sessions also suggested that the content should be short and digestible in easily accessible formats.

To meet this need, we produced short content videos that directly address the science and engineering concepts and practices behind each unit. For example, the central learning goal of the Remote Sensing unit is for learners to understand how light can be used to study the surface of planetary objects, like Mars, so they can design devices to explore the planet and find a safe landing zone. We saw in observations that, when educators did not fully explain the relevant concepts, learners built models in the engineering design activity, such as the LiDAR straws model, without knowing how or why their models could be applied to planetary science. The short professional development video we designed for this activity defines the relevant properties of light and shows examples of LiDAR remote sensing technologies. When educators themselves understand key science and engineering concepts, they can build context and meaning for program participants as they work to meet engineering challenges. For the three units, we created eight videos, ranging in length from 40 to 75 seconds. Using these videos, educators can get a basic understanding of key science and engineering concepts for a whole unit in five or ten minutes. Before they facilitate a day's activity, they can easily go back to access the video on that specific topic.

Tier 3: Pedagogical Support

As OST educators become more comfortable with managing activities and content, they can turn their attention to supporting youth development. The third tier

Figure 4. Sample STEM Activity Learning Progression



of professional learning helps OST educators incorporate effective strategies to foster 21st century skills, social and emotional development, youth agency and identity, and STEM habits of mind.

The needs assessment revealed that many OST educators are focused on building 21st century skills, including communication, critical thinking, collaboration, and leadership skills. Tier 3 resources help with this effort. One document offers open-ended questions aligned with the steps in an engineering design process. For example, when learners are investigating materials that might be used in an engineering design solution, the document states that the goal of this activity is to clarify language and help learners develop a common vocabulary for evaluating the properties of the materials. An OST educator might therefore ask, “What do you mean when you say this material is ‘squishy’? Does anyone have additional words to describe that property?”

To give OST educators strategies for building STEM habits of mind, we created downloadable resources to build understanding of these habits and suggest strategies for fostering them. The documents provide suggested strategies and questions to encourage learners to envision multiple solutions, negotiate design decisions collaboratively, design and follow fair scientific processes, persist through failure, and celebrate successes.

Still in development for Tier 3 are resources to help OST educators connect STEM learning to young people’s real-world experiences and build their STEM identities.

Tier 4: Unit or Activity Extensions

When OST educators have their basic needs met, so that they can to successfully facilitate activities and teach content, they are ready for the fourth tier of support: resources for unit or activity extensions. NASA offers a rich assortment of planetary science and engineering resources for educators and learners, including videos, lesson plans, fact sheets, career opportunities, image libraries, interactive digital learning platforms, and simulations. These resources can be sorted by missions, by themes, or by learning subjects and scientific concepts such as math, art, astrobiology, or geology.

Rather than recreate similar resources, PLANETS provides a filtered set of links to NASA resources related to the three curriculum units. Educators can use these resources as unit or activity extensions. For example:

> To connect young people to diverse STEM careers, educators can use short video clips about NASA careers like this one on Women in STEM: https://nasaeclips.arc.nasa.gov/video/smee/sme2-women-in-stem

> To make science and engineering learning relevant to young people's lives, educators can use the NASA Home & City interactive website to show how space exploration and research have affected daily life: https://www.nasa.gov/directorates/spacetech/new_interactive_website_homeandcity

> To delve deeper into unit content, PLANETS recommends resources like the interactive visualization of Mars at https://trek.nasa.gov/mars

Implications for Designing OST STEM Professional Development Resources

Effective OST educators can inspire STEM learning by supporting young people's curiosity and sense-making—without offering too much guidance, which can stifle learning (Fenichel & Schweingruber, 2010). OST educators need resources at different levels of STEM implementation in order to support young people in their own STEM learning. The PLANETS tiered approach to STEM professional development resources provides multiple options and entry points for OST educators so they can quickly and easily obtain the support they need just when they need it to implement the curriculum. This approach meets the immediate needs of OST educators in implementing STEM curriculum, supports their content and pedagogical needs in ways that are useful and directly applicable, and provides resources for further exploration beyond the curriculum. The web-based, modularized resources are available in short snippets to meet the needs of busy OST educators.

There is no "one size fits all" STEM professional development that will meet all the needs of OST educators. Each OST educator has unique environmental factors, content knowledge, experiences, interests, and skills that affect how they engage youth in learning STEM. They therefore need multiple options for specialized professional development resources. The PLANETS tiered approach is one approach to self-driven professional development. Though its effectiveness needs further investigation, the model may be adaptable for application with other OST STEM curriculum and professional development initiatives.

References

Afterschool Alliance. (2011). STEM learning in afterschool: An analysis of impact and outcomes. http://www.afterschoolalliance.org/stem-afterschool-outcomes.pdf

Allen, P. J., Noam, G. G., Little, T. D., Fukuda, E., Gorrall, B. K., & Waggenspack, B. A. (2017). Afterschool & STEM system building evaluation 2016. The PEAR Institute: Partnerships in Education and Resilience. https://stemecosystems.org/resource/afterschool-stem-system-building-evaluation-2016

Bloom, N. E., & Clark, J. (2017). *Assessing the content and instructional needs of out-of-school time educators for teaching integrated science and engineering curricula.* Center for Science Teaching and Learning, Northern Arizona University. https://planets-stem.org/wp-content/uploads/2019/12/PLANETS-e-poster-needs-assessment-final_120219.pdf

Bloom, N., Roberts, E., Rubino-Hare, L. Archer, H. N., Cunningham, C., & Clark, J. (2019, June 16). *How educators implement engineering curricula in OST settings* [Conference presentation]. American Society for Engineering Education 2019 Annual Conference, Tampa, FL, United States.

Bowie, L., & Bronte-Tinkew, J. (2006). *The importance of professional development for youth workers.* Child Trends. https://www.childtrends.org/wp-content/uploads/2006/12/child_trends-2007_06_15_rb_prodevel.pdf

Chi, B. S., Freeman, J., & Lee, S. (2008). *Science in afterschool market research study: A final report to the S. D. Bechtel, Jr. Foundation.* Coalition for Science After School, Lawrence Hall of Science, University of California, Berkeley. https://www.informalscience.org/sites/default/files/Science_in_After-School_Market_Research_Study.pdf

Chun, K., & Harris, E. (2011). *Research update 5: STEM out-of-school time programs for girls*. Harvard Family Research Project. https://archive.globalfrp.org/publications-resources/publications-series/research-updates-highlights-from-the-out-of-school-time-database/research-update-5-stem-out-of-school-time-programs-for-girls

Committee on STEM Education. (2013). *Federal science, technology, engineering, and mathematics (STEM) education: 5-year strategic plan.* National Science and Technology Council, Executive Office of the President. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

Fenichel, M., & Schweingruber, H.A. (2010). *Surrounded by science: Learning science in informal environments*. Washington: National Academies Press. https://doi.org/10.17226/12614

Freeman, J., Dorph, R., & Chi, B. (2009). Strengthening after-school STEM staff development. Coalition for Science After School, Lawrence Hall of Science, University of California, Berkeley. https://www.informalscience.org/sites/default/files/Strengthening_After-School_STEM_Staff_Development.pdf

Garst, B. A., Baughman, S., & Franz, N. K. (2014). Benchmarking professional development practices across youth-serving organizations: Implications for extension. *Journal of Extension, 52*(4). http://lib.dr.iastate.edu/extension_research/21

National AfterSchool Association. (2006). *Understanding the afterschool workforce: Opportunities and challenges for an emerging profession*. Houston: Cornerstone for Kids.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits.* Washington: National Academies Press. https://doi.org/10.17226/12190

Noam, G. G., & Shah, A. (2014). Informal science and youth development: Creating convergence in out-of-school time. *Teachers College Record*, *116*(13), 199–218.

Palmer, K. L., Anderson, S. A., & Sabatelli, R. M. (2009). How is the afterschool field defining program quality? A review of effective program practices and definitions of program quality. *Afterschool Matters*, *9*, 1–12.