

Enabling Science Learning: Effectively Providing a Direct Connection to the Science
A State of the Profession White Paper Submitted to the Astro2020 Decadal Survey

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Introduction:

As stated in *New Worlds, New Horizons in Astronomy and Astrophysics* (National Research Council, 2010), “astronomical research continues to offer significant benefits to the nation beyond astronomical discoveries. These benefits include its role in capturing the public’s attention and thereby promoting general science literacy and proficiency.” NASA has long recognized the importance of providing a return on the public’s investment in its science missions and research programs by using its unique assets to support education in science, technology, engineering, and mathematics (STEM) fields and scientific literacy.

Based on several factors, including recommendations from prior decadal studies and federal committees such as the National Science & Technology Council’s Committee on STEM Education, NASA’s Science Mission Directorate (SMD) has restructured its approach to what has traditionally been referred to as “education and public outreach.” In 2015, NASA’s SMD issued a cooperative agreement notice for proposals to “further enable NASA science experts and content into the learning environment more effectively and efficiently with learners of all ages” (NASA, 2015). The objectives² to be addressed by competitively-selected cooperative agreement awardees are to: enable STEM education, improve U.S. scientific literacy, advance National Educational Goals³, and to leverage through partnerships. Each award is required to partner with an external evaluator who is responsible for measuring the project’s success.

The resulting NASA Science Mission Directorate effort, named the *Science Activation* program (<https://science.nasa.gov/learners>), currently consists of 24 competitively-selected projects and their external evaluators, as well as a set of NASA-funded “infrastructure” projects that provide complementary products and services. The NASA Science Mission Directorate’s *Science Activation* program is currently in its fourth year of implementation, and offers a new strategy for leveraging the science and experts associated with NASA’s science missions and research programs to benefit the nation.

One example of a SMD-funded *Science Activation* project is the “NASA’s Universe of Learning” project (<https://www.universe-of-learning.org/>), created through a unique partnership between the Space Telescope Science Institute, Caltech/IPAC, Center for Astrophysics | Harvard & Smithsonian, Jet Propulsion Laboratory, and Sonoma State University. In this project, our multi-institution team works together to create and deliver a cohesive suite of astrophysics-themed products, programs, and professional learning experiences for *informal and life-long learning* environments. The primary audiences of the NASA’s Universe of Learning project are educators, youth, and adults in museums, science centers, public libraries, and other venues of free-choice learning, including online participation. The team also partners with undergraduate

² NASA Internships, Fellowships, and Scholarships and K-12 Educator Professional Development are addressed by NASA’s Office of STEM Engagement.

³ National Educational Goals are outlined in plans issued by the National Science and Technology Council’s Committee on STEM Education (2013, 2018).

faculty to incorporate astrophysics-themed materials into courses for future classroom teachers (pre-service educators)⁴.

The NASA's Universe of Learning project is designed to be responsive to the needs of its audiences and NASA's *Science Activation* objectives, and leverages the decades of experience our institutions have in conducting the science operations, hosting the data archives, and communicating the science for NASA Astrophysics missions and research programs. We describe the key characteristics of our approach below as a potential model for adoption.

Key Principles of the NASA's Universe of Learning Project: A Model for Potential Adoption

The NASA's Universe of Learning team works together to develop distinctive and inspiring resources and experiences that *enable youth, families, and lifelong learners to explore fundamental questions in science, experience how science is done, and discover the universe for themselves*. Key principles of the NASA's Universe of Learning project include:

- **Determination of audience needs.** The audience's need for products and activities is systematically established prior to development through the use of literature surveys, audience surveys, focus groups, or other evaluative means. For all projects funded through NASA SMD's Science Activation program, the first year of work focused on ensuring projects fulfill an expressed audience need.
- **A direct connection to current scientific research and the science community.** The NASA's Universe of Learning team is co-located with NASA astrophysics science and mission operations centers, mission data archives, and scientific research programs. This enables the team to easily incorporate current science and scientific expertise into NASA's Universe of Learning products and activities. Access to current science and scientific expertise is valued by our audiences, as indicated by external evaluation conducted by Cornerstone Evaluation Associates. When asked to rank the most interesting and useful features of professional learning experiences, participants identify "being part of conversations highlighting new science results" as one of the top three features.
- **Active involvement of "Subject Matter Experts" (scientists and engineers).** Subject Matter Experts (SMEs) within and external to the NASA's Universe of Learning team are actively involved in the conceptualization, development, and delivery of our products and activities. A variety of studies show the value and challenges associated with involving SMEs in informal education and public outreach, including external evaluation of our work conducted by Goodman Research Group and Cornerstone Evaluation Associates. We involve SMEs in our work in a highly focused way, based on their interests, available time and areas of scientific expertise. We seek to involve SMEs from groups traditionally underrepresented in STEM fields as role models, as well as early career SMEs who

⁴ The scope of the NASA's Universe of Learning project does not include materials or professional learning experiences for K-12 classroom educators, aside from our partnerships with university faculty who are instructing pre-service educators.

connect well with youth audiences. Our approach and the roles in which we involve SMEs are based on an assessment of the needs of the science community conducted by Goodman Research Group. A “subject matter expert” database leveraging STScI’s My Space Telescope (MyST) proposer database⁵ is in development to facilitate the involvement of a broader cross-section of the science community.

- **Grounding in best practices and research in informal learning.** NASA’s Universe of Learning products and activities are tied to strands of informal learning (Bell et al. 2009), and informed by national education standards (e.g. Next Generation Lead States, 2013) and education research on ideas held by the public that are inconsistent with scientific knowledge (alternative conceptions / preconceptions / misconceptions) (e.g. Sadler et al., 2010; Coble et al., 2013; Trouille et al. 2013).
- **Serving groups traditionally underserved and underrepresented in STEM fields.** Our portfolio of products and activities includes a variety of offerings designed to engage and support audiences traditionally underserved and underrepresented in STEM fields. These include exhibits and community-based programs serving girls and their families and rural audiences, coding workshops in partnership with organizations such as Black Girls Code, and a variety of 3D and tactile materials. External evaluation of our Girls STEAM Ahead with NASA events shows the impact on learning and interest is greatest for those girls who meet a scientist.
- **A cohesive approach and portfolio of products and activities.** The NASA’s Universe of Learning team has developed a framework of science content themes and research-based strands of informal learning that unify its portfolio of products and activities and provide pathways, or progressions of experiences, for learners. This characteristic of our work is designed to address concerns of fragmentation in prior studies of federally-funded education programs (NSTC, 2013).
- **Attention to program and project management.** Integrating expertise and work flows across institutions requires attention to program and project management. Our team includes a PMP (Project Management Professional) certified Program Manager.
- **Partnerships and collaboration at multiple levels.** In addition to the partnership between our institutions, we partner scientists, educators, communication specialists, and production specialists to ensure products and activities are scientifically accurate, reflect how people learn, and address audience needs. We also partner with a range of organizations and *Science Activation* projects to extend the reach and impact of our products, activities, and expertise, leveraging principles defined in social science research (Santo, 2017). External evaluation of our multi-institution partnership

⁵ The STScI MyST database contains SME data collected over the nearly three decades of Hubble Space Telescope operations and is also used to construct SME panels for evaluation of NASA Hubble Fellowship Program postdoctoral applications.

demonstrates effectiveness on key research-tested criteria of successful collaborations (Mattessich et al., 2001).

- **External evaluation and metrics of success.** Our team partners with Goodman Research Group and Cornerstone Evaluation Associates to provide rigorous external evaluation of the NASA's Universe of Learning portfolio of products, programs, and professional learning experiences, as well as to evaluate the multi-institution partnership itself. Our evaluation leverages best practices in the evaluation of informal learning programs such as the NSF *Framework for Evaluating Impacts of Informal Science Education Projects* (Friedman, 2008).

Incorporating NASA Astrophysics Assets into the Learning Environment

The NASA's Universe of Learning team uses the principles outlined above to create and deliver four categories of learning resources and experiences. These categories are based on our direct connection to mission data, discoveries, and SMEs spanning all of NASA Astrophysics, and the power of those data, discoveries, and SMEs to inspire engagement and learning in STEM, as well as our institutional expertise and audience needs. The four categories are: Data Tools and Participatory Experiences, Multimedia and Immersive Experiences, Exhibits and Community Programs, and Professional Learning Experiences.

The NASA's Universe of Learning team uses a thematic approach to create, disseminate, and evaluate products and experiences that support learners, for example, in understanding how scientists use the electromagnetic spectrum to learn about our universe. During the first four years of our award, our institutions worked together to identify current images and datasets from across NASA's Astrophysics missions and transform these assets into captivating visualizations, engaging video products, online interactives, and hands-on experiences with data and physical renderings of data. We also delivered live webinars featuring Subject Matter Experts to support informal educators in using the science content and resources with their audiences, engaged girls at public libraries to increase their STEM awareness, brought NASA content to rural and underserved communities, and trained pre-service teachers at minority serving institutions to use NASA resources in their classrooms.

This approach is a direct result of the NASA SMD's *Science Activation* program's emphasis on thematic projects that are designed to support learning based on the needs of the audience. This emphasis enables our team to draw upon and integrate content from across all of NASA's Astrophysics missions and research programs.

Recommendations

Based on these experiences, we encourage the Decadal Survey committee to consider the following recommendations:

A) As research by the astrophysics community has become increasingly team-based, multi-wavelength and in some cases, multi-messenger, we endorse a similar approach towards

astrophysics-inspired STEM learning and outreach efforts, including collaborations and partnerships across organizations to achieve common goals.

B) Astrophysics-themed STEM learning and outreach activities should utilize current science to support their learning goals based on audience needs. This is best accomplished by partnering scientists who are directly connected to current scientific research with experienced educators, communications professionals, and external evaluators.

C) Astrophysics STEM learning and outreach activities should increase the diversity of individuals serving as subject matter experts, as well as providing access to underserved and differently abled communities.

D) Collaborations and partnerships between STEM learning and outreach efforts funded by different agencies should be encouraged.

Concluding Remarks:

Numerous studies and reports indicate a continuing need to strengthen scientific literacy and critical thinking among youth and adults, including developing an understanding of the process of science. Astronomy is perhaps unique among the sciences in its potential to inspire and engage the public, as evidenced by the widespread public interest in major astronomical discoveries emerging from NASA's space-based observatories and NSF ground-based observatories. Ongoing support from federal agencies such as NASA and NSF and active involvement from the science community is a necessary component in strengthening scientific literacy and critical thinking over the next decade. The work of the NASA Science Mission Directorate's *Science Activation* program can offer a model for the coming decade.

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