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Best Practices in NASA's Astrophysics Education and Public Outreach Projects

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Abstract. NASA's Astrophysics Education and Public Outreach (EPO) program has partnered scientists and educators since its inception almost twenty years ago, leading to authentic STEM experiences and products widely used by the education and outreach community. We present examples of best practices and representative projects. Keys to success include effective use of unique mission science/technology, attention to audience needs, coordination of effort, robust partnerships and publicly accessible repositories of EPO products. Projects are broadly targeted towards audiences in formal education, informal education, and community engagement. All NASA programs are evaluated for quality and impact. New technology is incorporated to engage young students being raised in the digital age. All projects focus on conveying the excitement of scientific discoveries from NASA's Astrophysics missions, advancing scientific literacy, and engaging students in science and technology careers.

1. Introduction

Almost two decades ago, NASA's Astrophysics Education and Public Outreach (EPO) program started on a modest scale, with the goal of infusing new science from NASA missions into school curricula, inspiring students to go on to careers in science and engineering, and in improving scientific literacy in the general public. All missions were required to include EPO programs in their budget, and research scientists were offered opportunities to propose EPO efforts. The Science Mission Directorate (SMD) has developed standards for its EPO programs, in order to ensure excellence and uniformity across its portfolio. Through the years, the programs evolved resulting in a number of best practices, which led to an enrichment of the programs and placed them on a solid foundation.

A key factor in the success of NASA EPO has been the partnering of science and education expertise. Scientists and educators work together to prepare standards-based education resources and professional development at the K–12 level, articulating cutting-edge scientific discoveries and reinforcing core science concepts. Outreach experts in science museums and planetaria develop products for the general public in collaboration with mission-based scientists and educators. Local, regional and national partnerships increase NASA's reach in disseminating its scientific content.

Attention is paid to audience needs while developing programs, particularly with respect to underserved and underrepresented populations. For example, EPO programs have been targeted towards girls, visually impaired, hearing impaired individuals, rural audiences, and the rapidly expanding Spanish speaking population in the US. Other key best practices include the maintenance of digital repositories for easy access to the public, infusion of new technology, the development of cross cutting programs across science and technology, and a regular professional evaluation of all SMD EPO programs.

The NASA Astrophysics Forum provides coordination across all programs. Forum tasks include identifying gaps that need to be addressed based on audience needs and areas where programs can work together to maximize efficiency and minimize duplication of effort, maintaining communication with providers of SMD-funded EPO through monthly telecons and a community webpage, assisting NASA in collecting evaluation metrics, and maintaining a single point of entry to SMD education materials: NASA Wavelength.[1] The four SMD Forums work together to learn from each other and develop and share best practices. Some examples of best practices are given below.

2. Partnering of Science and Educational Expertise

In this section, we describe some innovative programs where scientists have partnered with educators to help them analyze NASA data, acquire an authentic research experience by flying on board the Stratospheric Observatory for Infrared Astronomy (SOFIA), and in taking NASA content into classrooms through curriculum development and professional development of teachers. Creating strong partnerships plays a critical role in the sustainability of the programs.

2.1. NASA/IPAC Teacher Archive Research Program (NITARP)

Teachers competitively selected for the NITARP program are partnered with an astronomer at the Infrared Processing and Analysis Center (IPAC) for a year-long authentic research experience. Teams of teachers and students analyze data from the NASA archives at IPAC and present their results at the American Astronomical Society. The teachers are also required to share their experience with their colleagues and provide professional development. They learn to work long distance with each other using data from NASA archives in conjunction with NASA scientists via electronic means. This ability has a long lasting effect as the teachers can continue this experience even after the NITARP funding ends. A multiplier effect is obtained by the professional development workshops they provide as NITARP ambassadors.[2]

2.2. SOFIA Airborne Astronomy Ambassadors

The SOFIA Airborne Astronomy Ambassadors (AAA) program has selected twenty-four teachers in 2014 to partner with scientists on research projects, and participate throughout the research from preparation and observations to data analysis. Like the teachers in previous AAA program cycles, they will fly on the SOFIA aircraft and acquire data. These partnerships at 43,000 ft. have resulted in the development of

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[1] `nasawavelength.org`

[2] `http://nitarp.ipac.caltech.edu/`

teaching material for students, conduct of professional development workshops, and presentations by the AAA, impacting thousands of students and teachers.[3]

2.3. Pennsylvania Three Region Math and Science Partnership (MSP) Program

The MSP provides professional development (PD) to teachers as part of a three-year partnership between scientists at the Space Telescope Science Institute (STScI), Goddard Space Flight Center (GSFC), and educators in seven universities in Pennsylvania. The goal of MSP is to increase the academic achievement of 30,000 students in mathematics and science by enhancing the content knowledge and teaching skills of classroom teachers. Scientists and educators partner to deliver the latest science and educational practices, including Hubble Frontier Fields observations and how they apply in the classroom setting. In-person workshops supported by follow-on PD opportunities provided via *Google+* are conducted. Data collection for an external evaluation of the PD series is in progress.

3. Responding to Customer Needs

In addition to programs that have a wide impact, NASA Astrophysics EPO providers have also responded to specific customer needs and have targeted programs to address them. One of the key objectives of SMD's EPO vision is to identify customer needs, so as to develop high impact programs. Some examples include the *Cosmic Times and Space Forensics* program, engagement of Girl Scouts in NASA mission EPO, *Astrophysics Educator Ambassadors*, and taking NASA science to non-traditional audiences.

3.1. Cosmic Times and Space Forensics

The GSFC Astrophysics EPO team held educator focus groups prior to developing *Cosmic Times*. There was a resounding message for a need for science-based readings from outside of textbooks. Such readings would help teachers fulfill education standards for cross-curricular literacy, including today's Common Core requirements. The GSFC team responded with two programs that bring student-oriented readings into science curriculum support materials.

Cosmic Times is a series of six front-page newspapers with dates chosen to highlight key moments in the past century that lead to our current understanding of the universe. Each "issue" includes student readings at differentiated reading levels and standards-aligned lesson plans in science, language arts, and social studies. This has been distributed since 2009.[4]

Space Forensics takes students through astronomy narratives that parallel crime scene forensics. Each standards-aligned *Space Forensics* case uses mystery narratives and hands-on activities to take students through the process of scientific problem-solving. The first three cases introduce the "forensics" of supernova remnants, supermassive black holes, and gamma-ray bursts. Distribution begins late 2014/early 2015.[5]

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[3] `https://www.sofia.usra.edu/Edu/programs/ambassadors/ambassadors.html`

[4] `http://cosmictimes.gsfc.nasa.gov/`

[5] `http://pcos.gsfc.nasa.gov/epo/`

3.2. Astrophysics Educator Ambassadors

Sonoma State University supports a cohort of *Educator Ambassadors (EA)* (or master teachers) under the auspices of Fermi, Swift, XMM-Newton, and NuSTAR missions. The EAs help develop, test, and disseminate educational material based on the science from these missions. The master educators in this program have trained over 65,000 other teachers since 2001. Comprehensive evaluation of the workshops conducted by the EAs has been overwhelmingly positive.

3.3. Engaging Girls through Girl Scouts

Through participation in the NASA-funded *Small Satellites for Secondary Students (S4)* project developed by Sonoma State University, Girl Scout teams learned how to build payloads. With the help of AeroPac, they then launched them on model rockets at a field near Chico, California, and analyzed flight data. This hands-on program gave the students both engineering and data analysis experience.[6]

The James Webb Space Telescope (JWST) Near Infrared Camera (NIRCam) has had a long-standing EPO program with the Girl Scouts. An educational day with the students was held at GSFC when NIRCam was delivered to GSFC. The students were able to view JWST hardware in the clean room at GSFC, and participated in activities such as math games, signing a *Go Girl Scouts* banner, and making a start cycle bookmarker.[7]

3.4. Astronomy Festival on the National Mall

Originally started with a NASA grant to address the needs of non-traditional audiences, the Hofstra University sponsored program, *Astronomy Festival on the National Mall*, returned to Washington DC in the summer of 2014. It featured optical and radio telescopes, exhibits, *Visions of the Universe* posters, hands-on activities, multimedia presentations, and a chance to meet astronomers. Volunteers from several local organizations set up 20 telescopes on the Mall. Starting at 6 pm, lines of 20–30 people waited at each telescope to view sunspots and close-up views of the Moon, Saturn, Jupiter, Mars, colorful double stars, and star clusters. Tourists, scouts, and visitors met important historical astronomers: Caroline Herschel (Lynn King), Tycho Brahe (Dean Howarth), and Johannes Kepler (Jeff Jones).[8]

3.5. Keeping up with New Technology

The NASA Science Mission Directorate EPO community has increased the impact of NASA resources by making effective use of new technology. We present here two examples—one which demonstrates how educational resources are disseminated widely through the program *NASAWavelength* and *AstroPix*, and another in which a digital learning environment is provided to teach astronomy.

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[6] http://s4.sonoma.edu/

[7] http://zeus.as.arizona.edu/~dmccarthy/GSUSA/

[8] Video:http://nsf.gov/news/mmg/mmg_disp.jsp?med_id=76428

3.6. Digital Repositories

The SMD Forums have organized NASA educational resources in user-friendly categories, keeping in mind the variety of audiences that may access them. The website[9] leads the user systematically to the material they may find useful. Educators may retrieve material to develop teaching plans, students may use them to help with their homework or satisfy their curiosity, and the general public may use it to increase its knowledge of NASA science.

Over 5,000 images from NASA Astrophysics missions are easily accessible via AstroPix,[10] developed by the Infrared Processing and Analysis Center (IPAC). Designed for the non-specialist, this website introduces the user to a tantalizing collection of astronomical objects and guides them to information about them.

3.7. Planck Mission in Virtual Reality

The Planck mission EPO team is experimenting with teaching astronomy in a virtual immersive environment. They have tested out their virtual reality simulation with 50 volunteers, all students at University of California, Santa Barbara, in May and June 2014. The students, who came from a diverse ethnic population, were pre-tested using questions from the Astronomy Diagnostics Test (ADT) about lunar phases and solar eclipses. They were then guided through an exploration of the Earth-Moon-Sun system in the virtual solar system, and given some time to explore on their own, for a total of 30 minutes of exposure. A post-test containing the same questions re-arranged and an opinion survey, showed larger gains for the same questions after the 30-minute guided experience in the virtual solar system than published learning gains for thousands of students, using the ADT, over the course of an introductory Astronomy course. Further study is planned.

4. Cross-cutting Topics across NASA Science/Technology

NASA's science and technology is inextricably intertwined, and presents an opportunity to present both in an engaging way to the public and the educational community. We present examples of two different approaches to taking NASA science and technology from NASA missions to the public and into classrooms.

4.1. Chandra-led Public Science Projects

Through a series of projects, *From the Earth to the Universe (FETTU)*, *From the Earth to the Solar System (FETTS)*, and *Here, There and Everywhere (HTE)*, the Chandra mission EPO team has effectively presented multiwavelength astrophysics, planetary science and astrobiology, heliophysics, atmospheric science, Earth Science, physics, and the science of light to diverse audiences. The FETTU[11] and FETTS[12] exhibits consist of high-resolution images from astronomy and the solar system. These images

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[9]`http://nasawavelength.org`

[10]`http://astropix.ipac.caltech.edu`

[11]`http://chandra.harvard.edu/impact/fettu.html`

[12]`http://chandra.harvard.edu/impact/fettss.html`

are publicly available from websites. Key features of the programs are: high quality driven by science results, needs defined through local organizations, accessible to public audiences, and "viral" results at relatively low cost through online public repository. Both FETTU and FETTS have become a trusted, valuable science resource. They have served millions through exhibitions at airports, museums, parks, and other public venues across the world. Evaluation shows learning gains and increased interest in astronomy. The HTE[13] program connects cross-cutting scientific content with everyday phenomena. It is available to the public through exhibits with supporting hands-on-material and online. Preliminary evaluations show that the connection to known phenomena helps generate excitement and a desire to learn in the non-specialist.

4.2. JWST STEM Innovation Project (SIP)

The SIP is an interdisciplinary program that allows students and educators to explore the real challenges currently facing NASA researchers as they design and build the Webb telescope. Initiated as a pilot in New York and California, the SIP is now underway in all 50 states with over 300 schools signed on to participate. Students research JWST and participate in project-based learning experiences that focus on real-world engineering applications and reinforce STEM skills. A growing body of academic research supports the use of project-based learning in schools as a way to engage students and increase motivation, reduce absenteeism, reinforce cooperative learning skills, and improve test scores. The SIP also promotes awareness of STEM careers.

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[13] `http://chandra.harvard.edu/impact/hte.html`