NASA GSFC Opportunities for STEM Professionals Using the Vantage Point of Space

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Abstract

NASA has a variety of learning opportunities for STEM professionals. Three opportunities at GSFC are examined in this chapter: 1) standard summer research and development internship for undergraduates, 2) senior internship for undergraduate and graduate students and 3) a workshop series for informal learning center professionals. We describe these programs, examine their evolution with respect to most effective education practices and their assessment and evaluation, and identify the similarities and differences between them. The internship programs highlight authentic project-based research and development experiences with the senior internship providing a richer, deeper, and more demanding experience that has greater professional value. The workshops for informal learning center professionals on-the-other hand, focus on building knowledge of GSFC's science and engineering strengths among these professionals, and on building enduring partnerships between individuals (participants and GSFC scientist, engineers and educators) and between organizations (GSFC and the informal learning center). Finally, we examine the characteristics of these programs from a design and management perspective. Through this examination we identify a general structure that provides insight into more effective design and management of similar education programs.

Introduction

Learning opportunities have been a key part of NASA's educational activities since the beginning of the agency. When NASA was established in 1958, its charter directed the agency to *provide for the widest practicable and appropriate dissemination of information concerning its activities and the result thereof* [1]. Today, this charge includes a full range of education and public engagement activities for adults and children. Initially much of NASA education focused on faculty and graduate student participation in NASA's research and engineering endeavors via fellowships and internships. That focus continues today with expanded participation of undergraduates in authentic engineering and scientific research and development (R&D) projects. Additionally, in recent years NASA has recognized the importance of informal education both to capture the interests and imagination of children and adults when linked to formal education and vice versa [2]. With that recognition have come strategies to expand the use of NASA's knowledge products in informal settings and to provide coordination and coherency between the formal and informal offerings for all audiences, from elementary to college students, parents and the public.

As the science and technology (S&T) workforce for the entire country approaches retirement age, and the demand for S&T professionals grows, the issue of developing individuals to meet current and pending workforce needs increases in importance [3, 4, 5]. When coupled with demographic shifts (the U.S. is fast becoming majority minority) and the low participation of minority populations in S&T careers, these concerns heighten [6, 7, 8]. The ability of the U.S. to retain its competitive edge in this vital economic arena is dependent upon its ability to produce a highly talented and innovative S&T workforce in sufficient quantity to fulfill the demand [9, 10].

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To do this, we must apply all of our resources in ways that are known to be effective for

1) Inspiring and engaging all children in and about science and technology, and
2) Motivating engaged children, young adults and college students from diverse backgrounds to excel in STEM courses of study and develop the habits-of-mind required of computer scientists, engineers or scientists.

Capitalizing on the linkage between formal and informal education is one way that NASA can inspire, engage and motivate students, and help students develop the habits-of-mind they will need to successfully prepare for careers in science and technology [11, 12].

The scholarly work in education has matured since NASA's formation. With that maturity has come a deeper understanding of highly effective education practices in informal and formal settings and the recognition of the interconnection between them [13, 14].

As one might expect, a student's learning path meanders between formal and informal education environments and adult students engaged in NASA Goddard Space Flight Center's (GSFC's) internships are neither engaged in traditional formal nor in traditional informal education (unstructured "free choice" learning environments) [15, 16]. They are in fact engaged in a learning experience somewhere between these two extremes.

In their NASA GSFC internship, students are applying the knowledge they have acquired in their formal curriculum-structured academic setting to their research project in an informal, research-structured setting. This transference of knowledge from a curriculum to a research-structured environment tests the students' depth of understanding and their ability to extend their understanding in new and different ways. This transference and extension begins and deepens the development of the habits-of-mind required of successful scientists and technologists [17, 18, 19].

Linking this learning to the student's curriculum and continuing the development of these habits-of-mind is a critical element in shaping future scientists and technologists. This linkage is especially important for underrepresented and underserved populations since they often come from environments where there is little exposure to individuals with careers in science or technology, or those who possess these habits-of-mind [15, 20].

With this context in mind, we will focus on two education endeavors at GSFC for STEM learners; 1) authentic research and development internships for college students and 2) authentic STEM partnerships with educators at science and technology centers and museums who develop and deploy NASA educational programs or create exhibits for the public.

RESEARCH AND DEVELOPMENT INTERNSHIP OPPORTUNITIES FOR COLLEGE STUDENTS

The NASA Goddard Space Flight Center has for many years operated summer internship opportunities for undergraduate and graduate students. These opportunities have provided authentic research or development experiences designed to benefit both the intern and the mentor. These experiences have also provided a set of extensions that vary with the internship opportunity or the research or development experience. Internship extensions have included field experiences, coaching on preparation of a poster or oral presentation, career networking events, and team projects.

Historically, these opportunities focused on one-time internships for individuals without explicit consideration of workforce supply or on-going development of the individual. They typically provided an informal research experience with little attention to the on-going career development of the intern once the intern returns to the formal curriculum-structured education setting. The general rational was passive. It was thought that exposure to research or development efforts at GSFC was sufficient to motivate students to excel in their academic studies [21, 22]. Should NASA or GSFC never see the intern again, it was hoped that s/he would become a high performing contributor to the S&T workforce pool.

That perspective was refocused in NASA's 2011 Strategic Plan [23] that recognized *hands-on experiences are unparalleled in their ability to develop a student's advanced STEM skills and prepare them for a career*. Consequently, NASA seeks to support formal higher education degree programs by *providing undergraduate and graduate students with hands-on opportunities to contribute to our current missions* (Goal 5.1), and to "*work hand-in-hand with colleges and universities to provide student research and engineering experiences that contribute to our missions*". (Goal 6.1)

In all areas of vital interest to GSFC, this means encouraging and mentoring promising undergraduates and graduate students, especially those from fast growing underrepresented populations, to excel in their degree programs. In the sciences, this means encouraging promising students to matriculate to graduate school and eventually qualify for the NASA hiring pool. In engineering, this means the focus is on the development of professionals at the baccalaureate level.

Intern placement records and focus group discussions reflect the existence of multiple-year placements with no coordinated broadening of perspective or more formal development of those individuals. Mentors, in some cases, recognized the value of a continuing research experience when integrated with an intern's academic program as a way to promote the matriculation of and academic development of a particularly promising intern. Clearly, students who return for a second or third year, especially to the same mentor, have impressed that mentor with their performance. Such individuals would likely benefit from a deeper more demanding research or development experience, especially when linked to their academic program. Likewise, mentors would benefit from that intern's work. Ultimately, one would expect these interns to rise to the top of the workforce pool from which GSFC and its contractors draw.

Standard College Internship Opportunity

In 2008 and 2009 GSFC began experimenting with the structure and organization of its student internship programs by incorporating improvements designed to strengthen the linkage between an intern's curriculum-structured academic background and their interests, and a mentor's research and development project needs. GSFC began an improvement path grounded in educational research and on feedback and input from the GSFC mentor and intern community [24]. Previously, most interns were accepted into an internship program and then placement was sought with a mentor (a scientist, engineer, or other staff).

Of the 26 internship programs at GSFC-Greenbelt, only half have participated in the improvement efforts described here. With time, it is anticipated that most internship programs will migrate to a model that improves the linkage between the intern's curriculum-structured academic background and the mentor's project.

Initially two fundamental changes were made—

1) Instead of GSFC Office of Education placing interns, mentors posted authentic research or development project descriptions and students applied to them by writing a short essay describing their interest in the posted project and their qualifications for that project, and
2) Selection of students for placement with a mentor was made by the mentor; not by the education program. Mentors selected multiple interns who applied to their project and the education office using advice from a placement panel placed one of the selected interns with the selecting mentor.

These changes addressed a concern voiced both by mentors and by interns. Mentors were given a critical role in the selection of interns and students were allowed to apply to projects of interest to them.

As the selection and placement processes changed so did the coherency ~~of internship~~ opportunities. Beginning in summer 2010, all interns at GSFC-Greenbelt, irrespective of the education program in which they were placed, were offered the opportunity to participate in a set of coherent extensions beyond their research or development project (Table 1).

Beginning in 2011, a single coordinated opening ceremony on the first day of the internship and a single closing ceremony at the end of the summer experience were added to the activities. All 340 interns from 26 programs were strongly encouraged to participate in these events and in the professionally organized poster session for interns at the end of the session.

To facilitate their participation in the poster session, interns were offered the opportunity to attend a special training session on preparation of oral presentations and poster sessions for execution at scientific or technical conferences. About half of the interns at GSFC took advantage of the opportunity to prepare a poster and to interact with the science and engineering community at GSFC and with their peers in this forum. They participated in the culture of science and engineering and furthered the development of habits-of-mind and the behavioral and communication skills required of scientists and engineers [15, 19, 25].

As these changes were occurring a multi-year formative evaluation was conducted to assess the demographic make-up of the intern participants and the effectiveness of these changes for both mentors and interns. In addition to demographics, student questions focused on program logistics, the student's perception of their experience and their working relationship with their mentor. The response of interns to these questions has guided program improvements since 2009.

Answers to questions about intern performance and the interns' perception of their internship experience provide insight into the overall value of the internship opportunities to both mentors and interns. All mentors were offered the opportunity to provide input on the performance of their intern. The percent of mentors who responded increased over the 3-year period (2009-2011) from 40% to 75%. Of these mentors over 60% thought highly of their intern, considering the intern to be a *top performer*. Moreover, more than 90% of mentors who responded were satisfied with the intern's performance and would like the intern to return. Likewise interns generally had very favorable experiences, with about 60% interested in returning for a second internship or beginning a career with NASA GSFC. In all years, about 11% of the interns were uninterested or ambivalent about returning or beginning a career with NASA.

The demographic data collected during the formative evaluation indicates that the GSFC intern programs are quite effective at attracting high quality female and minority students. This is of special interest to NASA since GSFC's disciplines of interest are those that have the lowest representation of women and minorities in national statistics; physical sciences (e.g., physics, chemistry, and astronomy), engineering (aerospace, chemical, electrical, material, mechanical), computer science, and Earth sciences (ocean, land, and atmosphere) [6, 7]. Nationally, in 2011 25% of the U.S. baccalaureate degrees in these fields were women, while the participation rate of females in GSFC summer internship programs (dominated by these disciplines) was 36%, 11% higher than the national graduation rate/participation rate.

Table 1: Extensions Offered to All Interns at GSFC

Orientation:

A half-day ceremony in which interns meet each other and their Center Advisor; receive an introduction to NASA GSFC from the Center Director and others; an introduction to their summer experience from their Center Advisor; meet their mentor; and visit the laboratory where they will carry-out their research or development project.

Career Networking Event:

A day long event in which interns are introduced to the range of careers at NASA GSFC via a panel session, the employment opportunities and processes, and a structured networking event where interns can meet and speak with employees and management from various organizations within GSFC.

Professional Seminar:

A renowned NASA scientist or engineer gives an engaging seminar on their research or development work. The seminar is designed for a science/engineering attentive audience and assumes the listener is interested in the topic but is not an expert. In 2010 and 11, Dr. John Mather, NASA's only Nobel Laureate, was the speaker.

How to Prepare a Professional Seminar or Poster:

An interactive presentation providing very practical guidance on preparing and presenting a professional oral presentation or a poster. Authentic examples of best practices, and issues to consider when preparing your poster or presentation are provided. The presenter is a GSFC science and engineering professional that gives presentations and posters as part of their professional responsibilities.

Professional Poster Session:

Preparation and participation in a professional poster session using standards of a professional meeting and attended by the science and engineering community at GSFC.

Closing Ceremony:

A half-day ceremony in which interns receive their certificate of participation and say farewell to their peers, mentors, and new colleagues.

The ethnic and racial diversity of the interns was also quite broad and reflects the multi-year effort GSFC has undertaken to identify and recruit diverse, high-quality internship applicants within these science and engineering disciplines that are critical to GSFC's work. For example in 2008, GSFC's internship programs were highly successful at recruiting African American and Hispanic students (two groups traditionally underrepresented in the sciences and engineering) [6] into its internship programs when compared to the proportion of degrees awarded.

Table 2: Diversity by race/ethnicity in GSFC internship programs compared to the US population and to science and technology baccalaureate degrees in GSFC disciplines*

Race/Ethnicity	**2008[$] % of U.S. Population**	**2008[$] Degrees Awarded (% of total in category)**	**2008 GSFC-Greenbelt Internship Participation (%)**	**2011 GSFC- Greenbelt Internship Participation (%)**
White	66	64%	49	61
Asian American	4.3	10	10	8
African American	12.2	6	17.1	20
Hispanic	15.5	7	15.5	7.4
Native American/Native Peoples	2.4	0.5	2.3	0.6

* GSFC related science and technology disciplines (computer science, engineering,, physical sciences (physics, chemistry, astronomy, other), Earth sciences (land, atmosphere, ocean), mathematics and statistics)

§ Data from National Science Foundation, 2011a

In addition to the 2009 survey, in 2011, a more detailed exit survey of interns was administered, one that provided insight into qualitative aspects of an intern's summer experience at GSFC. The survey results highlight several strengths and identified areas for improvement. The research or development project focus of internships at NASA GSFC is their primary strength. Over 70% of the interns were *extremely satisfied* with their internship experience, while suggesting several areas where improvements were needed. Most interns (95%) indicated that the activities offered to all interns were beneficial to them. Comments from individual interns indicated that the *career-networking event* and the *presentation and poster preparation session* were most beneficial.

Interns identified three major areas for improvement. The first and most requested area spoke to logistical concerns covering housing, transportation, receipt of announcements, pre-arrival information, and security including access to GSFC facilities needed to carry-out their project. The second area of concern was tied to adequate preparation for the intern's arrival or mentoring for the intern when the mentor was unavailable. The third area was a request for more exposure to GSFC—its facilities, research and development activities—beyond their project, and more forums for social engagement among the interns.

In addition to the responses discussed above, high interest was expressed by both mentors and interns for an opportunity targeting returning interns. Accordingly, the NASA-GSFC Office of Education undertook a needs assessment of GSFC stakeholders[1] in 2011 and a test of extensions previously recommended for returning interns. The assessment sought to identify the broad interest and the specific needs for an internship opportunity targeted to returning interns, while the test sought to identify effective extensions from the previous recommendations. The

[1] GSFC Stakeholders in this context are employees of NASA who lead organizations, mentor undergraduate or graduate interns or fellows, or highlight issues related to diversity and equity in the workforce.

extensions (Table 3) exposed interns to a range of unique facilities and expertise at NASA GSFC and HQ, not offered via the standard internship.

Table 3: Summer 2011 Test of Extension Experience for Returning Interns

Science and Technology Research and Development Extensions
Small group discussions with senior NASA leadership • Agency Leadership for Education, Technology, Science, and Scientific International Partnerships • GSFC Leadership for Science and Technology, Science and Exploration, a Nobel Laureate
Behind the scenes facility tours of GSFC guided by the facility leadership • Scientific Visualization Facility • Integrated Design Center • Rocket design, build and launch facilities • Aircraft facilities • Balloon design and test facilities

The interns who participated in this test were most inspired by the visit with NASA's Chief Technology Officer and NASA's Chief Scientist, and the behind-the-scenes, guided tour of GSFC's Wallops Flight Facility. The tour of Goddard facilities included rare access to NASA facilities and discussions with NASA scientists, engineers and managers not available to interns or most NASA employees.

Senior Internship Opportunity

The findings from the needs assessment and the extension experiment led to the formation of a *Senior Internship Opportunity*. An experimental pilot is planned for summer 2012. The unique and innovative aspects of this internship are 1) creation of a professionally meaningful product by the intern, 2) coupling of a summer research experience with an academic year segment that allows completion of the research begun during the summer, and 3) joint mentoring of the intern during the academic year by the GSFC mentor and a local faculty advisor. Research has shown that linking students' academic programs to their summer internship, both before and after the internship, can improve their academic outcomes. Students gain scientific and cultural understanding as they participate in the culture of science with a mentor that helps move them toward full membership in the science community as they gain knowledge and self-confidence to deal with the inherent challenges of STEM research [25, 22, 18, 15, 17].

To qualify for this opportunity, applicants must have participated in a previous GSFC internship while a college student and must provide the following as part of their application:

1) A strong letter of support from their previous NASA GSFC mentor
2) The name of an academic faculty advisor ~~for~~ to oversee the academic portion of the research or development project
3) A well thought-out outline for their proposed research or development project and a detailed outline for a final *professionally-meaningful product*.

Table 4: Senior Internship Opportunity

Opportunity Components
Internship Requirements

1. Intern has had a previous college internship at GSFC.
2. Provide letter of recommendation from a previous NASA GSFC mentor.
3. Write a well thought out outline for the research or development project they wish to complete during their second (continuing) internship and a detailed outline for the final professionally meaningful product they will produce.
4. Provide name of a faculty advisor at home institution for the project to which they are applying.
5. Student produces a professionally meaningful product at end of academic segment; mentor, advisor and student formally agree on product at beginning of summer segment.
6. Ten-week summer segment and 6-9 month academic year segment.
7. GSFC mentor supports and provides guidance to intern during entire project lifecycle; mentor, advisor and intern work together to provide coordinated advice, guidance and local support to intern during academic segment of internship.

Summer Segment Extensions

1. Overview of a NASA field center (NASA GSFC) from senior management's perspective.
2. Exposure to interpersonal networking and team building skill development.
3. Informal seminar series among participants and their GSFC mentors.
4. Insiders tour of unique facilities at GSFC (e.g., scientific visualization; instrumentation integration facilities; aircraft, balloon and rocket facilities).

As designed, the Senior Internship opportunity requires a greater commitment from the mentor and the intern than other GSFC internships. As well, there is an added commitment of a faculty advisor at the intern's home institution. The mentor will be engaged with the intern during the entire lifecycle of the internship (summer segment and 6-9 month academic year segment). The intern works independently while seeking advice and guidance from the GSFC mentor during the summer segment. The mentor, in-turn, guides and challenges the intern's critical thinking and analysis skills, and encourages reading or examination of the literature.

The mentor will also interact with and establish a collaborative working relationship with the intern's faculty advisor at the intern's home academic institution. With the intern, they author an agreement at the beginning of the internship describing the deliverable the intern is to produce. The faculty advisor and the GSCF mentor work hand-in-hand to provide advice, guidance and assistance to the intern as the project is completed and the final deliverable is prepared. An additional benefit of these student-focused, collaborative relationships are new, mutually beneficial research partnerships between GSFC mentors and academic advisors of interns. In the long-term, it is envisioned that these colleague-to-colleague relationships will lead to sustainable institutional partnerships, especially with small or minority serving institutions.

SCIENCE AND ENGINEERING WORKSHOPS FOR INFORMAL LEARNING CENTER PROFESSIONALS

Separate from and in addition to the internship opportunities described thus far, GSCF informal education is involved in a three year pilot study with select small- to medium-sized museums in the Goddard Region (Virginia to Maine). The purpose of the study is to infuse current NASA content into and to develop long lasting partnerships with the museums.

Small- to medium-sized museums and science and technology informal learning centers (ILCs) were targeted because of their significance in the community. Many are important sources of engagement and inspiration, as well as being places where underserved populations can experience and build understanding of the innovations in science and technology [26, 14, 12].

To grow this vision, these centers must be able to routinely infuse their facility with new and engaging programs and materials, which is a significant challenge for most. Many lack funds to hire experts to assist in the design or creation of new exhibits and programs or to update or refurbish existing services [27].

Recognizing these centers serve an audience that NASA may not reach and their fiscal constraints can be addressed by NASA, GSFC saw an opportunity for a fruitful partnership. NASA GSFC has science and technology innovations, and the communication and education resources that are of interest to these centers, while these informal learning centers serve an audience that GSFC would like to reach. Consequently, in 2010 GSFC piloted the first in a series of science and engineering workshops for the professional staff at these learning centers.

The purpose of the workshop was to support these centers by providing timely and engaging content for their exhibits and programs, and to build enduring partnerships with them. The model included a two-day workshop for their exhibit and education program professionals at GSFC and periodic updates and communications. The workshop focused on information and resources related to GSFC science and technology. Information and resources that could both invigorate exhibit content was packaged and ready for use.

As with NASA's internship programs, informal learning center professionals applied to the workshop and met a set of application requirements. This process was used to ensure the best match of potential partners—informal learning center size, objectives, interests, and needs—with GSFC offerings. Like with the internships, applicants were required to provide a recommendation reflecting their capability and interest. Unlike the internships, an endorsement was required by both the applicant and the supervisor. The endorsement agreed to commit the organization to using NASA content in their facility. It further agreed to evaluate the new or improved program or product. As with GSFC internships, successful applicants were provided a stipend. In this case, the stipend was used to implement within their center a new or refurbished program or product. The intent was to encourage use by reducing the cost to refresh a program or create a new exhibit or program using the NASA content.

Two pilot workshops were held in 2010 and 2011 and a third is planned for 2012. Ten to 15 informal learning centers participated each year with four of the centers from 2010 returning in 2011 (Table 5). The centers represent the spectrum of small- to medium-sized informal learning centers located in the northeastern U.S. (GSFC's service area). They range from science centers, to museums, to observatories. They serve different primary audiences (e.g., school groups, the public, educators), from urban, rural or both. All service diverse populations.

Table 5: Attributes and interests of participating informal learning centers

Year	Attendees (Num)	Institution	Location	Facility Visitors	Area of Interest	Track Placement	URL
2010	2	Carnegie Science Center	PA, Pittsburg	~700,000 visitors/yr;	Earth Science Heliopphysics	Climate change Life cycle of a star	http://www.carnegiesciencecenter.org/
2010	2	DaVinci Science Center	PA, Allentown	More than 80,000 participants/yr	Earth Science Planetary Science	Climate change Lunar Science	http://www.davincisciencecenter.org/
2010	2	Delaware Aerospace Education Foundation (DASEF)	DE, Symrna	19,000 participants from 101 schools; 450 programs for teachers and 4500 for the public	Planetary Science	Lunar Science	http://www.dasef.org/
2010	2	Discovery Museum and Planetarium	CT, Bridgeport	~55,000 children participants/yr	Planetary Science Astrophysics	Lunar Science Space Weather	http://www.discoverymuseum.org/
2010	2	Kopernik Observatory and Science Center	NY, Vestal	Not Available	Earth Science Heliopphysics	Climate Change Life cycle of a star	http://www.kopernik.org/
2010	2	Maryland Science Center	MD, Baltimore	~500,000 visitors/yr	Earth Science Astrophysics	Climate Change Space Weather	http://www.mdsci.org/
2010	2	McAuliffe Shepard Discovery Center	Not Available	Not Available	Earth Science Heliopphysics	Climate Change Life cycle of a star	http://www.starhop.com/
2010	2	Museum of Natural History & Planetarium RWP	RI, Providence	Primarily school groups	Heliophysics Astrophysics	Life cycle of a star Space Weather	http://providenceri.com/museum/
2010	1	New England Air Museum	CT, Hartford	Not Available	Earth Science	Climate change	http://www.neam.org
2010	1	Rochester Museum & Science Center	NY, Rochester	Not Available	Heliopphysics	Life cycle of a star	http://www.rmsc.org
2010	2	Wings of Eagles Discovery Center	NY, Horseheads	Not Available	Earth Science Planetary Science	Climate change Lunar Science	http://www.wingsofeagles.com
2011	1	Clay Center for the Arts and Sciences of West Virginia	WV, Charleston	Not Available	None Specified	NASA Mission Design	http://theclaycenter.org/
2011	1	DaVinci Science Center	PA, Allentown	More than 80,000 participants/yr	Engineering Planetary	NASA Mission Design	http://www.davincisciencecenter.org/

						MESSENGER/Mercury	
2011	1	Discovery Museum and Planetarium	CT, Bridgeport	~55,000 children participants/yr	Astrophysics Engineering	NASA Mission Design Our Universe	http://www.discoverymuseum.org/
2011	2	Fairbanks Museum and Planetarium	VT, St. Johnsbury	Not Available	Heliophysics/Earth Science Planetary/Astrophysics	Climate Change MESSENGER/Mercury	http://www.fairbanksmuseum.org/
2011	2	Kopernik Observatory and Science Center	NY, Vestal	Not Available	Planetary/Engineering Heliophysics/Astrophysics	NASA Mission Design Our Universe	http://www.kopernik.org/
2011	2	Maryland Science Center	MD, Baltimore	~500,000 visitors/yr	Heliophysics Astrophysics	MESSENGER/Mercury Our Universe	http://www.mdsci.org/
2011	1	Montshire Museum of Science	VT, Norwich	150,000 visitors/yr; about 72,000 are school children; rural	Earth Science	Climate Change	http://montshire.org/
2011	4	Morehead Planetarium and Science Center	NC, Chapel Hill	160,000 visitors/yr; 85,000 school children	Earth Science None specified None specified Astrophysics	Climate Change NASA Mission Design Our Universe	http://www.moreheadplanetarium.org
2011	2	Museum of Science and Technology	NY, Syracuse	180,000 visitors/yr; about 30,000 school children; urban, inner-city	None specified None specified	Climate Change Climate Change	http://www.most.org/
2011	2	The Robert J Novins Planetarium	NJ, Toms River	Located at a community college	None specified None specified	Our Universe Our Universe	http://www.ocean.edu/planet.htm
2011	1	Sciencenter	NY, Ithaca	97,000 visitors/yr; about 4,700 are school children; underserved community	None specified	MESSENGER/Mercury	http://www.sciencenter.org/
2011	2	Science Museum of Virginia	VA, Richmond	NO INFO on website	Earth Science Heliophysics	Climate Change NASA Mission Design	http://www.smv.org/
2011	1	Tellus Science Museum	GA, Cartersville	125,000 visitors/yr; about 45,000 school children	Planetary Science	MESSENGER/Mercury	http://www.tellusmuseum.org/

2011	1	William Miller Sperry Observatory	NJ, Cranford	Located at a community college	Astrophysics	Our Universe	http://www.asterism.org/

Each workshop was built upon the assessed effectiveness of the previous one. In 2010 and 2011 the workshops were divided into subject matter tracks so participants could focus on areas most relevant to the mission and current initiatives of their facility. Moreover, the tracks were rotated from year-to-year so the workshop is of interest to a broad range of informal learning centers in the northeastern United States and to returning participants. About one third of the 2010 participants returned for the 2011 pilot.

Placement of participants in tracks was based on their interest and participant-limit for each track. Each morning, unifying topics and community building were tackled in a plenary session. In that session, GSFC scientists and engineers engaged participants in over-arching and cross-cutting topics relevant to the tracks such as available multimedia resources, (http://svs.gsfc.nasa.gov/) and the digital learning network (http://dln.nasa.gov/). Participants engaged in community building efforts such as peer-to-peer networking among participants, reflection of morning speakers and the previous days' events, and a share-a-thon. In the afternoon they delved into the subject matter of their track, such as climate change, the universe, engineering, the sun, the moon, Mercury/MESSENGER.

The focus of the 2011 and the upcoming 2012 workshops were identified in part by formative assessments from the 2010 and 2011 workshops, respectively. The intent of this approach is to engage participants and is well supported by the research [28]. Based on participant input, an engineering track, designed to integrate GSFC scientific study areas, was added in 2011. The other three 2011 tracks focused on recent scientific discoveries and emerging scientific concepts related to our universe, planet Mercury, and climate change on Earth.

For each track, GSFC scientists and engineers led the forum. They provided engaging activities, behind the scenes tours of relevant facilities, timely science highlights, engaging visual resources to illustrate these highlights, and illustrations to unpack complex scientific concepts. As an example, the overarching aspects of the engineering track were introduced in the plenary session—highlighting the diversity and breadth of engineering at GSFC. The track then provided an in-depth view into the engineering lifecycle, mission operations, instrument development at GSFC, and the integrated mission and instrument design center. Track participants engaged in interactive discussions with GSFC engineers while addressing each of these topics. These interactions included "up-close-and-personal" guided visits to facilities where workshop participants could see and experience first-hand the engineering principles presented in the discussions. In all cases, participants were provided with presentation materials and on-line resources they could utilize in their programming when they returned to their informal learning centers.

A critical aspect of the 2011 workshop, and for the one planned for 2012, is the community-building component. The intent is two fold: 1) to build deep relationships with organizations that will endure as individuals at the informal learning centers and GSFC change, and 2) to foster development of a community of practice among professionals at small- to medium-sized informal learning centers including the professionals at the GSFC Visitors Center.

To frame the community-building efforts, the workshop organization, and the application and selection processes were designed to foster the development of these deep relationships between

GSFC and the small- to medium-sized informal learning centers. Specifically, requiring applicants to provide endorsement of participation and commitment from their management to utilize workshop resources in their programming was designed to begin building this relationship.

The acceptance and follow-through by participating centers to integrate workshop content into a program or exhibit within the following 12 months and to undertake an assessment and evaluation of that effort, once deployed, demonstrated commitment on their part to a relationship with GSFC. Likewise, GSFC offered to provide follow-through with each of the informal learning centers as they integrated content into a program or exhibit. To that end, GSFC provided a primary point of coordination and facilitated the development of multiple linkages between these organizations and the GSFC through the now-familiar subject matter experts that had presented and guided workshop activities.

Connecting the informal learning centers and their education professionals with the GSFC subject matter experts and with GSFC educators fostered the development of numerous professional connections between GSFC and these centers. This relationship model uses these linkages, between GSFC professional staff and the informal learning centers, as a means for the relationship 1) to endure the vagaries of staffing changes and 2) to provide expertise to the participants as they utilize the resources provided during the workshop to create or refurbish programs and exhibits.

Another mechanism to deepen the GSFC/ILC relationship was the reservation of workshop seats, each year, for those informal learning centers that participated in a previous workshop. In this way, ILCs could stay engaged with GSFC and receive continuous update for programs and exhibits. Between workshops, the GSFC coordinator provided regular updates to participants and kept in touch via a number of formal and informal mechanisms. The coordinator tracked activities at the ILCs resulting from the workshop experience, supplied learning resources and materials for special events (such as sun-viewing glasses for the once-in-a-100-years Transit of Venus event), and provided a virtual professional development opportunity for participants and their local colleagues.

The share-a-thon and the peer-to-peer networking events were added in 2011 in response to 2010 participant input. These too were intended to build and support the newly established community of practice among the informal learning center education participants. These events provided expanded professional opportunities, for these educators from similar professional environments, thereby fostering professional relationships and future partnerships. With seats reserved for participants returning from a previous workshop, the first time attendees were linked to previous workshop organizations and content through the peer-to-peer networking with these returning participants. Moreover, GSFC provided both a workshop website where workshop materials could be shared and a list serve for participants to communicate with each other.

As a result of these partnership-building workshops, participants in 2010 and 2011 reported using a wide range of NASA resources in their programming. Those resources varied in nature from technology resources to education techniques (Table 6) with the learning resources and the subject matter expert resources being used the most. Of those who created or refurbished a program or an exhibit incorporating the NASA content, some made major additions to a permanent exhibit (existing or newly created) while others made additions to educational programs for children or for educators (Table 7). Several infused the new content into all categories of their center's programming: exhibits, education programs, and special events. All facilities targeted middle school aged (7 to 11 year olds) children, their teachers or their families. Some also targeted elementary and high school students.

Table 6: Nature of NASA materials utilized as a result of the workshop experience

Center⁺	Technology	Web	Learning Resources	Printed Materials	Subject Matter Experts	Education Techniques
2010						
1	✓	✓	✓			
2	✓	✓	✓			
3			✓		✓	
4	✓	✓	✓		✓	
5			✓			
6	✓	✓	✓		✓	
7			✓		✓	
2011						
1	✓	✓	✓		✓	
2			✓	✓		
3		✓				
4	✓	✓	✓	✓	✓	
5	✓		✓	✓	✓	✓
6		✓	✓		✓	
7			✓		✓	
8		✓	✓	✓	✓	✓

⁺numbers indicate a different informal learning center

Table 7: Informal learning center programming that benefited from 2010 workshop participation*

Center	Activity Changed/Created	Frequency
1	New Planetarium show	Long-term exhibit
1	Science-on-a-Sphere show	2 days
1	One day event	Repeat during school year
2	Middle school activities on the life of stars	Regular repeat cycle
3	Planetary Walk	Long-term exhibit
3	Summer camps (6) on various topics	Repeat in summer
4	Summer programs for children: 1) Space exploration 2) Space and Engineering Rocketry	Repeat during school year
4	Summer camp for children: The Milky Way	Repeat in summer
4	Public program on moon rocks	2 days
5	Space Day	Repeat once
6	Summer camps (3) for	Repeat in summer

	children on different topics	
7	Space and Aviation Day	Repeat once
8	Space weather programs	Repeat in summer

* Data for 2011 not available at time of publication

The NASA content delivered though these small- to medium-sized informal learning centers touched the lives of at many tens of thousands of individuals through permanent exhibits where visitor engagement lasted anywhere from a few seconds to a few minutes. In 2010, sustained engagement also occurred with about 260 children (elementary through high school) who participated in summer camps (three to 5 days) and in all day science programs at these centers.

The centers that participated in the workshops in 2010 and 2011, generally, were able to offer these programs and events only because of their participation in these NASA Goddard workshops. Clearly, being able to access timely resources and subject matter experts at NASA GSFC to update programs and exhibits is highly valued by these centers. As one workshop participant stated, *we (small informal learning centers) make a lot happen with a little*.

As we move forward, the long-term value of these workshops and the resulting partnerships between NASA GSFC and small- to medium-sized informal learning centers will continue to be assessed. To date, our research indicates that small- to medium-sized informal learning centers make effective partners for GSFC and vice versa and that the ILCs appreciate and include NASA content as they are able in their exhibits and programs.

CONCLUSION

NASA Goddard has a long history developing STEM professionals. As Goddard's educational activities have diversified and matured over the years so has the understanding of the relationship between those activities and the ability to move individuals along the learning pathway from exposure and inspiration to deep exploration and learning in an area of science and engineering. Today GSFC recognizes the critical role of STEM professionals in that pathway—from professional research scientists and engineers to professional science educators in the classroom and in informal learning venues.

Here we have presented three of our STEM development programs, two for individuals preparing to become scientific researchers or engineers and one for informal education professionals. When these learning experiences are compared (Table 8) it is clear that they are characterized by a common set of criteria.

Table 8: Comparison of learning experiences for STEM professionals.

Criteria	**Learning Experiences**			**Unifying Concepts**
	Informal Learning Center—Professional Development	**Internship-Standard**	**Internship-Senior**	
Environment	✓Small group workshop setting ✓Continuing interaction during following year and beyond	✓Individual research or development laboratory setting	✓Individual research or development laboratory setting at academic institution and at S&T research	Small groups

			facility	
Nature of Engagement	✓Hands-on engagement with guest speakers	✓Hands-on summer research or development experience	✓Hands-on summer and academic year research or development experience.	Interactive
Product	✓Institution commitment to use within 1 year in ✧museum education programs ✧public displays ✧interactive exhibits ✓Assessment and evaluation plan, survey instruments and collected data	✓Some portion of a product	✓Professional product appropriate to discipline	Produce a product
Anticipated Outcome	✓Expand specific knowledge of NASA content ✓Acquired education resources ✓Information on effectiveness of deployed assets ✓Know what GSFC does, and facilities required to accomplish that work	✓Engage in authentic scientific research or technology development ✓Know what NASA does and the facilities to accomplish its work ✓Expanded scientific or technical knowledge	✓Participation in and completion of an authentic scientific research or technology development project ✓The culture of science and engineering at NASA ✓Expanded scientific or technical knowledge	Expand Knowledge
Assessing and Evaluating Achievement of Objectives	✓Post experience survey of participants ✓Report of programs created, revised, or extended ✓Report of participants and the extent of their engagement with new or enhanced programs at learning center	✓End-of-internship on-line survey (SOLAR system) ✓End of internship exit interviews	✓Pre- and post-survey of mentors and students ✓Exit interviews of mentors and students ✓Report of effective processes, areas for improvement, and achievement of objectives	Measure effectivenes s
Network and Community Building	✓Relationships with NASA engineers, scientists and educators ✓Peer-to-peer relationships between museum professionals in northeast ✓Ad hoc interactions via email, phone, and events calendar ✓Formal community gathering via web and NASA's digital learning network	✓Mentor-Student ✓Research or development team ✓Peer-to-peer relationships	✓Mentor-Student-Academic Advisor ✓Peer-to-peer relationships	Culture and community

These criteria provide a common structure to the learning experiences—structure that is derived from the research on most effective education practices [14, 13, 15]. When criteria are compared across the learning experiences unifying concepts emerge even through the specifics for each learning experience may be different. As an example consider, *the Nature of Engagement* criteria. In all learning experiences, *interaction* between the participant and those guiding the learning is a key element of the experience. The differences arise in the specific nature of those interactions; in the case of the informal learning center professionals they are interacting with GSFC scientists and engineers, with GSFC educators, and with their peers. The participants in the internship programs on-the-other-hand are engaged in an intensive research activity with a mentor, the mentor's research or develop team, and in the advanced internship, the intern's academic advisor. It is important to recognize these similarities and differences so that maximum value can be obtained from both.

There is an increasing recognition of the important role human networks and community building play in the STEM profession and, therefore, their importance in the development of STEM professionals [15, 25, 19]. A key element of a successful learning experience that provides long-term career value for informal educators and young scientists or engineers is one that provides mechanisms to develop the socialization and behavioral skills necessary to be successful in their chosen field or to bridge the culture differences between fields. The modification of the informal learning center professionals' workshop in 2011 to include more opportunities for networking and community building was a direct response to this increased awareness. Likewise, the standard internship provides a career networking opportunity so all interns have an opportunity to practice professional networking skills. The Senior Internship opportunity builds upon this event and goes a step further. It provides formal training in networking and in team building, recognizing that the academic programs of S&T students often do not provide opportunities to develop these skills.

Furthermore, immersing interns or informal learning center professionals in research and development settings where partnerships are key to a project's completion helps them understand the key role partnerships play in today's science and technology. And it exposes them to the networking and team building skills required for partnerships to be successful.

Taken together these programs demonstrate how GSFC is continuing to do what NASA does best: offer opportunities for cutting edge science and engineer experiences in out-of-school and lifelong learning environments, and the application of our science and engineering habits-of mind to the practice of education. All opportunities immerse participants in the NASA culture on a NASA center where participants work side-by-side or interact frequently with NASA scientists and engineers. These opportunities employ the latest knowledge of most effective practices for development of STEM professionals. They seek to advance the understanding of those practices by carrying out assessment and evaluation that identifies which aspects of the science and engineering experiences are effective, which are not, and why. And finally, they provide insights into more effective design and management of education programs by the identification of common structural elements and unifying concepts among successful programs.

References

[1] National Aeronautics and Space Act, Public Law 85-568, (1958).

[2] M. Syvertson, J. Koke, S. Voirol, M. Kirkpatrick, J. Schoemer, T. Nolan, and N. Normandy, *NASA is Listening—Collaborations between NASA Earth Science Enterprise and the Informal Education Community*, National Aeronautics and Space Administration internal report (2000).

[3] Business Roundtable, *Tapping America's Potential: The Education for Innovation Initiative*, Business Roundtable, Washington (2005). http://businessroundtable.org

[4] National Science Board, *America's Pressing Challenge—Building a Stronger Foundation: A Companion to Science and Engineering Indicators–2006*, (2006), NSB-06-02.

[5] C. Coble and M. Allen, *Keeping America Competitive: Five Strategies To Improve Mathematics and Science Education*, Education Commission of the States, Denver (2005). http://ecs.org

[6] National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2011*. Division of Science Resources Statistics, National Center for Science and Engineering Statistics, Arlington (2011), Special Report NSF 11-309.

[7] National Science Foundation, *Characteristics of Scientists and Engineers in the United States: 2006*. Division of Science Resources Statistics, National Center for Science and Engineering Statistics, Arlington (2011), Special Report NSF 11-318.

[8] F. Hobbs and N. Stoops, *Demographic Trends in the 20th Century*. U.S. Census Bureau, Census 2000 Special Reports, Series CENSR-4. U.S. Government Printing Office, Washington (2002).

[9] Task Force on the Future of American Innovation. *The Knowledge Economy: Is the United States Losing Its Competitive Edge?* (2005). http://www.futureofinnovation.org

[10] N. Augustin, *Is America Falling Off the Flat Earth*, The National Academies Press, Washington (2007).

[11] J. H. Falk and L. D. Dierking, American Scientist **98**, 486 (2010).

[12] M. Fenichel and H. A. Schweingruber, *Surrounded by Science: Learning Science in Informal Environments*, National Research Council, Washington (2010).

[13] J. Bransford, A. L. Brown, R. R. Cocking, M.S. Donovan, and J.W. Pellegrino, *How People Learn: Brain, Mind, Experience, and School* Expanded Edition, The National Academies Press, Washington (2000).

[14] P. Bell, B. Lewenstein, A. W. Shouse, and M. A. Feder, *Learning Science in Informal Environments: People, Places, and Pursuits*, Committee on Learning Science in Informal Environments, National Research Council, Washington (2009).

[15] M. Pender, D. E. Marcotte, M. R. Sto. Domingo and K. I. Maton, *Education Policy Analysis Archives* **18**, 1 (2010).

[16] J. Bransford, N. Vye, R. Steverns, P. Kuhl, D. Schwartz, P. Bell, A. Meltozoff, B. Barron, R. Pea, B. Reeves, J. Roschelle, and N. Sabelli, *Learning Theories and Education: Toward*

a Decade of Synergy, In: P. Alexander, P. Winne (Eds.) *Handbook of Educational Psychology* (2nd Edition), Lawrence Erlbaum Associates Publishers, Mahwah (2006).

[17] S. J. Carey, *Peer Review* **12**, 1 (2010).

[18] J. Brownell and L. E. Swaner, *Five High-Impact Practices—Research on Learning Outcomes, Completion, and Quality*, Association of American Colleges and Universities (2010).

[19] E. Seymour, A. Hunter, S. L. Laursen, and T. Deantoni, *Science Education* **88**, 493 (2004).

[20] R. L. Morley, J. J. Havick, and G. S. May, *Journal of Engineering Education* **87**, 321 (1998).

[21] K. Kendricks and A.Arment, *Journal of College Science Teaching* **41**, 22 (2011).

[22] L. Sharp, B. Kleiner, and J. Frechtling, A *Description and Analysis of Best Practice Findings of Programs Promoting Participation of Underrepresented Undergraduate Students in Science, Mathematics, Engineering and Technology Fields*, (2000), NSF 01-31.

[23] National Aeronautics and Space Administration, *2011 NASA Strategic Plan*, National Aeronautics and Space Administration, Washington (2011), NP-2011-01-699-HQ.

[24] B. Meeson, NASA GSFC internal publication (2008).

[25] A. Hunter, L.S. Laursen, and E. Seymour, *Science Education* **91,** 36 (2007).

[26] L. D. Dierking, *Linking After-School Programs and STEM Learning: A View from Another Window*. Coalition for After-School-Science (CASS), New York (2007). http://www.afterschoolscience.org/pdf/member-publications/Linking After-School Programs and STEM Learning.pdf

[27] J. R. Hill, M. J. Hannafin, and D. P. Domizi, *Resource-based Learning and Informal Learning Environments: Prospects and Challenges*, In: L.W. Hin Tan and R. Subramaniam (Eds.) *E-Learning and Virtual Science Centers,* Information Science Publishing, Hershey (2005).

[28] P. H. Rossi, M. W. Lipsey, and H. E. Freeman, *Evaluation: A Systematic Approach, 7th ed*. Sage Publication, Thousands Oaks (2004).

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