LEARNING SUBGROUP

The Committee concluded that there has been <u>significant</u> achievement for the Learning outcome goal.

Introduction

The Learning Subgroup of the Advisory Committee for GPRA Performance Assessment was asked to assess activities at the NSF in the area of Learning. Specifically, it is a goal of the Foundation to *"cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens"* (NSF Strategic Plan FY 2006-2011).

Process Followed and Criteria Used

The Subgroup read and analyzed 159 highlights classified under the Learning outcome goal. Each member of the Subgroup reviewed approximately 53 highlights.

The Subgroup was asked to review and evaluate the accomplishments against one or more of the following criteria:

<u>Subgroup Members</u>

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K-12 Education

- *Support research to improve science and engineering education, and education research that develops successful models for teaching and learning.*
- *Support active involvement of K-12 teachers in NSF-funded research and workshops to bring fundamental knowledge and technological innovations into their classrooms*
- *Prepare the next generation of STEM professionals and attract and retain more Americans to STEM careers.*

Undergraduate Education through Postdoctoral Level

- *Develop creative, new pathways to engage students and researchers at the frontiers of discovery to facilitate their entry into the science and engineering workforce and enhance the skills and knowledge needed to advance their early careers.*
- *Broaden the participation of individuals underrepresented in STEM and diverse institutions throughout the United States in NSF-supported research and education activities and programs.*
- *Support community college faculty in NSF-funded research to bring fundamental knowledge and technological innovation into their classrooms.*
- *Support active research participation by undergraduate students in NSF-funded projects.*

- *Provide opportunities for international research experiences that enhance and strengthen undergraduate and postgraduate education.*
- *Prepare the next generation of STEM professionals and attract and retain more Americans to STEM careers.*

Public Understanding of STEM and Lifelong Learning

- *Increase interest, engagement, and understanding of science, engineering, and technology by individuals of all ages and backgrounds and within a variety of different formal and informal educational settings.*
- *Prepare and support the next generation of STEM professionals and attract and retain more Americans to STEM careers.*

Results of Analysis

The Subgroup selected the following highlights as examples of significant achievements in the area of Learning:

A significant number of projects contributed to creating a pre-school to postdoctoral STEM pathway that engages learners across all levels of schooling, involving learners in hands-on science, broadening participation, and increasing scientific literacy across age groups and backgrounds. Two examples are particularly telling of the cross-cutting nature of some of the initiatives in the portfolio.

Vast Facility in Appalachia Brings Students, Researchers Together (*Highlight ID 16111, Award 0520928)* describes a facility in Appalachia that studies cosmic ray sources. The project engages high school and college students in scientific research and outreach activities to members of the community. The location of the facility is unique, providing first-time access to advanced instrumentation for populations without a robust tradition of scientific research: students are given opportunities to make genuine and exciting discoveries. In sum, this project integrates successfully education, research, and societal benefit.

Another example is given in **New Flight Simulator Environment Engages Students in Interdisciplinary Research at Historic Tuskegee University** (*Highlight ID 15039, Award 0411464*), which describes a multidisciplinary, collaborative effort at Tuskegee Institute. The Flight Simulator Environment brings together aerospace engineers and psychologists in a quest to understand ways in which pilots make decisions during flight. Research on the topic was conducted by twelve Tuskegee students, and their work has great potential for societal impact, especially in the area of public safety.

In addition to these all-encompassing examples of excellence, the Subgroup also has identified projects that speak specifically to K-12 education, undergraduate education through postdoctoral level, and public understanding of STEM and lifelong learning.

K-12 Education

The portfolio of highlights provides many examples of work that engages learners across all levels of schooling and prepares K-12 teachers to create and deliver meaningful STEM curricula.

The enrichment of K-12 students through research experiences is an important theme found in the highlights. The work summarized in **Scientists and Students Online: An Oceanographic Expedition to the Indian Ocean** (*Highlight ID 16357*Award 0652315) exemplifies integration of pre-college students in a cutting edge research project through real-time tracking of an oceanographic expedition to the Indian Ocean. This ingenious use of the web resulted in increasing numbers of students tracking and participating in learning activities connected with the expedition. **COSMOS Students Become Rocket Scientists** (*Highlight ID 16417, Award 0602286*) describes a summer residential program at the University of California, San Diego (UCSD) that brings together high school students, undergraduates, graduate students, postdoctoral fellows, and faculty at UCSD with a focus on rockets.

The development of teachers is also an important feature of the portfolio. A Robert Noyce Scholarship program summarized in **Noyce Scholars Prepared to Teach in High-Need Schools** (*Highlight ID 14873, Awards 9852170, 0733849*) addresses the need to attract and retain the next generation of STEM professionals. The program has recruited 63 new math and science teachers to teach in high-need school districts in California, and 65 percent of the scholars have been drawn from underrepresented populations. In another similar example, **Vanderbilt University Biomedical Engineering Research Experience for Teachers** (*Highlight ID 15384, Award 0338092*), 44 teachers participated in a 24-day summer program with academic year follow-up. They completed a research project in a biomedical engineering laboratory, designed instructional units based on that research experience, and implemented them in their high school classrooms.

Project SEEDBed (**Stimulating Enthusiasm, Exploration, and Discovery through Biotechnology Education),** *(Highlight ID 14893, Award 0602744*) engages students and teachers from middle and high schools in summer academies at community colleges designed to increase knowledge, stimulate interest in biotechnology among students and teachers, and encourage students to pursue further study, possibly leading to careers as biotechnicians. Teachers are provided with "footlockers" to take back to their classrooms, with all of the equipment necessary to conduct new laboratory activities. Evaluation data indicate significant impact on both students and teachers.

In the project described in **Bringing an Atomic Force Microscope to School** (*Highlight ID 16213, Award 0653346*) high school teachers learn science through serious engagement with University of Wisconsin-Milwaukee faculty, with the science of CD-ROMs and DVDs as the focus. The effective and exciting use of technology in instruction is accomplished through classroom visits by UWM faculty who bring an Atomic Force Microscope to high schools as part of their instruction on the inner workings of CD-ROMs and DVDs. Broadening participation occurs through involvement of high school teachers.

A number of highlights summarize important work that teaches science in cultural context. **BPC-DP: New Voices and New Visions for Engaging Native Americans in Computer Science** (*Highlight ID 16501, Awards 0539982, 0540484*) describes a highly innovative pilot project that integrates Native American culture and experience with computer science. High school and college level students use computing to illustrate and display Native American art and culture to wider publics. By using the computer in culturally affirming ways, students are attracted to computer science and hopefully STEM work in general. The project should result in increasing the participation of Native Americans in computer science. It also illustrates the effective use of the computational sciences as a window for learning about arts and culture, as well as the use of arts and culture as a vehicle for attracting students to computer science. The project, if successful, should be highly replicable across regions and cultures.

WolfQuest: Learning Science through Game Play (*Highlight ID 15717, Award 0610427*) is a project that brings wolf behavior and ecology to life through exciting game play and intense social interactions for youth who are not normally attentive to ecological concepts and conservation issues. The WolfQuest game (www.wolfquest.com) represents a new model for informal science learning with practical, cultural, and ethical values embedded in the game's design. With an engaging online forum for learner-generated content, including art, stories, photos, and videos, WolfQuest has created a safe and engaging arena for youth. Removing the formal barriers typically found between scientists and the public, youth can talk directly with the world's leading wolf researchers as scientist role models. Striving to create new forms of science learning, in WolfQuest learners must engage experientially in authentic scientific problem solving using their reasoning skills to figure out complex scenarios regarding wolves and wolf survival without any external guidance. Because of its unique learning strategies, WolfQuest will aggregate data on learners' science content acquisition, attitudinal change, game engagement, and will ultimately yield new guidelines on effective practices for the future development of science education games and appropriate methodologies for evaluating game-based learning.

Undergraduate Education through Postdoctoral Level

A number of highlights described alternative pedagogical approaches to undergraduate science education. For example, a project summarized in **From Sausages to Skateboards** (*Highlight ID 15221, Award 0431756*), measured the impact of teaching real-life applications in undergraduate mechanical engineering courses. The research demonstrated that the use of applications had a positive impact on final course grades only when the whole course was applications based. Students in the application-based course had significantly higher final course grades than comparison students matched by instructor and course who did not receive application-based teaching or when only two or three applications were used during a course.

In a similar vein, **An Infrastructure for Designing and Conducting Remote Laboratories** *(Highlight ID 16031, Award 0326309*), describes a project consisting of an online laboratory environment that supports experiments based on multi-player computer game engines. This project aims to conceive, design, implement, test, and assess various online laboratory resources for undergraduate engineering and science education based on the use of advanced information technologies and of the rapidly expanding cyberinfrastructure. These online laboratory resources include remote experiments, virtual experiments, and virtual learning environments. Cyberinfrastructure-enabled educational tools such as this online laboratory environment show strong potential for initiating a dramatic shift in the general educational paradigm where the interactions between learners and educational resources as well as between

The portfolio has many examples of programs aimed at populations of students currently underrepresented in STEM disciplines (*Highlight IDs 14876, 15287, 15299, 15304, 15345, 15350, and 15389*). However insufficient data are provided to assess fully the outcomes and broader impacts of these initiatives. That having been said, some examples do stand out. A program at a university in Texas (**Undergraduates Discover the Thrill of Research**, *Highlight ID 15007, Award 0344221*) emphasized learning through discovery rather than by development of specific technical skills. The approach demonstrated success with inquiry-based exposure to scientific research, and the pilot group of 16 students won first place in a college-wide competition. In addition, two students from the group received awards for research presentations at the Louis Stokes Alliances for Minority Participation Program. Likewise, **Flying High in Louisiana** (*Highlight ID 16198, Award 0653423*), describes a curriculum revolving around small balloon science experiments and flight. These activities are designed to attract students from underrepresented groups into STEM programs and develop partnerships between Louisiana State University and local minority serving institutions. The students develop and conduct science experiments involving physics and thermodynamics. They create, launch, and bring to earth balloon

vehicles. The project involves minority youth in creative experiments, exposing them to physics and the process of scientific research.

Project Pathways (**Community College Students Discover Rare Mushroom in Texas**, *Highlight ID 15403, Award 0525536*) is a community college research project that has increased the number of students who obtained associate degrees or transferred to baccalaureate programs in science, technology, engineering, and mathematics (STEM) disciplines. Eastfield College students participate in research projects with various agencies. Some students were placed with U.S. National Park Service researchers and others in collecting data for the All Taxa Biodiversity Inventory of the Big Thicket. These data are used for national strategic planning related to a host of environmental issues. Additionally, the students collect data for their own research projects in biological areas of their choosing including botany, entomology, mycology, and ichthyology. The expedition to the Big Thicket enabled genuine scientific discoveries by students at the community college. Eastfield College is primarily a Hispanic serving institution. The students participating in Project Pathways are mostly first generation college students, women, African-American, Hispanic, or students with disabilities. The program often provides these students with critical first experiences in STEM. This project also illustrates how community colleges enhance infrastructure with major scientific instrumentation to integrate research and innovative teaching that advances discovery and scientific understanding for early undergraduates.

A very good model for global engagement of STEM students is NanoJapan (**Rice University PIRE Program Feated as Best Practice in International Education**, *Highlight ID 15598, Award 0530220*), a program of 12-week research internships in Japan for undergraduate engineering majors that has been awarded the 2008 Andrew Heiskell award for innovation in study abroad by the Institute for International Education. The NanoJapan program sends a diverse group of sixteen first and second year engineering majors from U.S. universities to leading edge nanotechnology laboratories throughout Japan to work with Japanese teams on research projects related to carbon nanotube fabrication. NanoJapan serves as a model for increasing study abroad and for participation of students in science and engineering fields. NanoJapan allows students to gain both experiences. Internships with world-class researchers in state-of-the-art facilities allow students to enhance engineering and research skills while building the cultural understanding, adaptability, and networks necessary to succeed in the global marketplace. This program has strong potential benefits in workforce development. In addition, the exposure of budding engineers to world-class nanotechnology expertise and facilities in Japan can be expected to enhance research and industrial engineering in the United States as participants advance in their careers.

Also noteworthy are the Pan American Advanced Studies Institutes (PASIs), which are jointly funded by the Department of Energy and the NSF (**Better (and More Sustainable) Living with Green Chemistry**, *Highlight ID 15261, Awards 0221274, 0617357*). A Sustainability and Green Chemistry PASI, organized by Dr. Mary Kirchoff of the American Chemical Society, was held in Mexico City, Mexico. Fifty-five graduate and postdoctoral students, nine local participants, and fourteen faculty members representing chemistry, pharmacy, biotechnology, packaging, genetics, nanotechnology,

and chemical, civil, environmental, and geo-environmental engineering participated in interdisciplinary activities and research to advance their knowledge of green chemistry and green engineering. Participants received educational materials and project ideas that could be implemented at their home university and within their local community. This project is an exemplar of interagency collaboration, global engagement, broadening science and engineering knowledge for sustaining the earth, and education extending to the postdoctoral level.

Public Understanding of STEM and Lifelong Learning

The portfolio is rich in examples of projects that enhance public understanding of science and engineering. Here we focus on three particularly innovative programs that cut across age groups. CYBERCHASE (**NSF-Funded CYBERCHASE Wins Emmy,** *Highlight ID 14955*, *Award* 0638962) is a ground-breaking multi-platform children's program on PBS KIDS GO! that shows the connection between mathematics and the invention process. The content spans the 3rd-5th grade standards of the National Council of Mathematics. The program has been awarded a daytime Emmy and reaches nearly five million viewers each week. It has recorded more than 1.7 billion page views for CYBERCHASE Online (http://pbskids.org/cyberchase/). Importantly, research shows that viewers take away the mathematics content of the episodes they watch and visitors spend more than an hour at the site on the average visit.

The Coalition on the Public Understanding of Science – COPUS (*Highlight ID 15556*, *Award* 0628790) is organizing the Year of Science 2009, a national year-long celebration of science to engage the public in science and improve public understanding about the nature and processes of science. COPUS is a growing network with over 180 registered participants that include professional societies, government agencies, business, universities, museums and informal science centers representing all major science disciplines. The network has an active website with information about the organization, national events, resources, and new participant registration. The database allows the public to search for COPUS related activities based on type, location, discipline, and target audience. To better coordinate COPUS activities, the network participants are organizing in regional and thematic hubs that will facilitate the interaction among network participants with common goals.

sLowlife: A Traveling Exhibit of Plant Science and Art (*Highlight ID 15586Awards* 0080783, 0416741, 0531641) is a novel multi-media educational/art installation including video, live plants, photographic prints, and interactive environments, originally designed by plant biologist Dr. Roger Hangarter in collaboration with an artist, Dennis Dehart. The exhibit highlights the research of Dr. Hangarter and is designed to convey to a public audience that plants are complex living beings and not just the ornamental inanimate objects many people assume. By combining time-lapse movies with artistic elements that demonstrate various plant movements and growth responses, the exhibit accurately and effectively combines science and art in a way that provides scientists and non-scientists

with a novel way of learning some basic plant biology and an appreciation of the dynamics of plant growth and movement. Contemporary research approaches, including a striking presentation of a genetic screen for tropism mutants in Arabidopsis, use of microarrays to understand plant growth, use of green fluorescent protein (GFP) to visualize the cytoskeleton, and views of chloroplast movement are mixed with classic experimental and educational demonstrations. With written commentary kept to a minimum, the visual impact of plants and experimental data dominates the experience in this novel exhibit.