NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE
NATIONAL RESEARCH COUNCIL

REPORT IN BRIEF

Preparing the Next Generation of Earth Scientists

An Examination of Federal Education and Training Programs

A strong earth science workforce is needed to help address issues that are important to the well-being of the nation—from the availability of fossil fuel, mineral, and water resources to a better understanding of geological hazards. Federal agencies play a key role in educating the next generation of earth scientists by offering programs that attract students to the field, support them through formal education, and provide training for an earth science career. The report examines 25 federal earth science education programs, describes ways to evaluate their success, and identifies opportunities for leveraging federal education resources. It also lays out a framework that shows how the various educational opportunities fit together, where stronger program connections are needed to move students along a path toward an earth science career, and where resources could be leveraged.

Demand for earth scientists is growing—the Bureau of Labor Statistics projects a 21 percent increase in the number of jobs for geologists and geophysicists and an 18 percent increase for hydrologists from 2010 to 2020. However, the number of graduates in earth science fields has not fully recovered from a sharp decline in the early 1980s, which was caused by a loss of U.S. jobs in the petroleum and mining industries (see Figure 1).

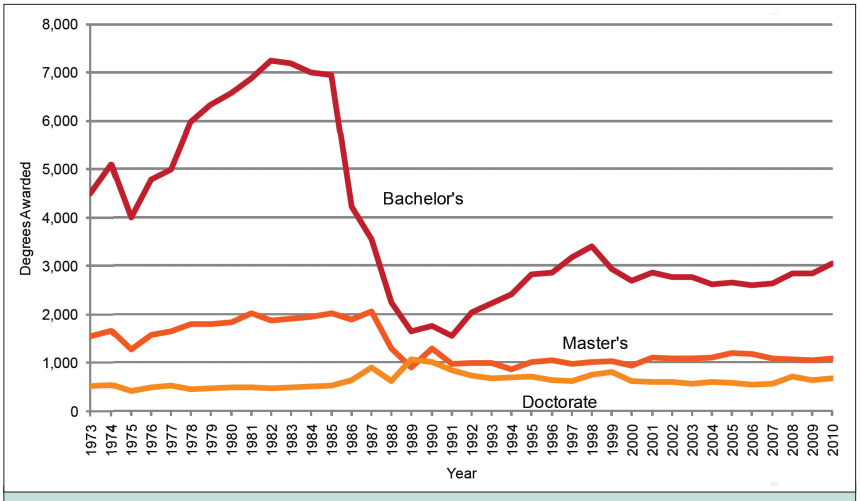

Figure 1. Trends in the number of geoscience degrees (defined in this figure as encompassing environmental science, hydrology, oceanography, atmospheric science, geology, geophysics, climate science, geochemistry, paleontology, environmental, exploration, and technical engineering and geoscience management) awarded at U.S. four year colleges from 1973 to 2009.

Source: Gonzales and Keane (2011)

Federal agencies offer earth science education programs for a variety of purposes, including supporting agency missions and helping to build a pool of qualified recruits. These programs raise awareness of the field and encourage the retention of students. Although these programs operate independently, they can be thought of as part of a larger system that moves individuals along a path to an earth science career.

This report considers 25 federal earth science education and training programs, lays out a conceptual framework for thinking about how these programs fit together, and suggests ways to leverage federal resources to improve recruitment of a diverse population to careers in earth science.

Program Framework

The 25 federal earth science education and training programs considered in this report (Box 1) provide a range of opportunities and experiences to attract individuals to the field

Box 1. Federal Earth Science Education and Training Programs Considered in This Report

National Science Foundation

- Earth Science Research Experience for Undergraduates (REU)
- Opportunities for Enhancing Diversity in the Geosciences (OEDG)
- Earth Sciences Postdoctoral Fellowship
- Geoscience Education (GeoEd)
- Global Learning and Observations to Benefit the Environment (GLOBE; with NOAA and NASA)
- Geoscience Teacher Training (GEO-Teach)

Department of Energy

- Office of Science Graduate Fellowship Program (SCGF)
- Summer of Applied Geophysical Experience (SAGE)
- Science Undergraduate Laboratory Internships (SULI)
- Community College Internships (CCI)

National Aeronautics and Space Administration

- Gravity Recovery and Climate Experiment (GRACE)

U.S. Department of Agriculture

- 4-H Environmental Education/Earth Science programs
- Agriculture and Food Research Initiative (AFRI) projects
- AFRI National Institute of Food and Agriculture Fellowships Grant Program

Environmental Protection Agency

- Greater Research Opportunities (GRO) Undergraduate Fellowships
- Science to Achieve Results (STAR) Graduate Fellowship Program

National Oceanic and Atmospheric Administration

- Educational Partnership Program (EPP) with Minority Serving Institutions

National Park Service

- Geoscientists-in-the-Parks Program (with the Geological Society of America)
- Geoscience-Teachers-in-Parks Program (with NAGT)
- National Fossil Day

Smithsonian Institution

- Leadership and Assistance for Science Education Reform (LASER) Program

and prepare them for employment. These programs fit within a framework that serves individuals at various stages of the earth science career pathway (see Figure 2). The stages of the framework are described as follows:

Awareness — Interest in earth science is sparked through formal education and informal learning in museums, after school programs, and groups. Examples include the USDA's 4-H Club and the National Park Service's National Fossil Day.

Engagement — Students actively engage in learning earth science by choosing earth science-related courses, clubs, or community service activities. Examples include the U.S. Geological Survey's Youth Internship Program, which offers hands-on earth science projects, and the National Science Foundation's Opportunities for Enhancing Diversity in the Geosciences program, which supports projects aimed at expanding the involvement of underrepresented groups.

Professional Preparation — Individuals acquire earth science-related job skills, knowledge, and abilities. Federally-sponsored research experiences help students build skills and expertise in a specialty area, for example, the National Science Foundation's Research Experiences for Undergraduates program. Internships, such as the U.S. Geological Survey's Hydrologic Technician Internship program, and postdoctoral positions introduce students and early career scientists to job opportunities and employers and provide work-related skills.

The particular pathway individuals take through the framework depends on their specific interests, the educational and career opportunities available to them, and the needs and expectations of their families. For example, some people might discover an interest in earth science through a family trip to Yellowstone; others by taking an outstanding introductory course in college. Understanding these pathways could help federal agencies design awareness and engagement programs that attract and retain a wide range of individuals.

Developing a System Approach

Federal earth science education and training programs operate largely in isolation from one another. The natural focus of most programs is on agency needs, and not on the larger goal of developing the future workforce. However, connecting federal programs and complementary programs

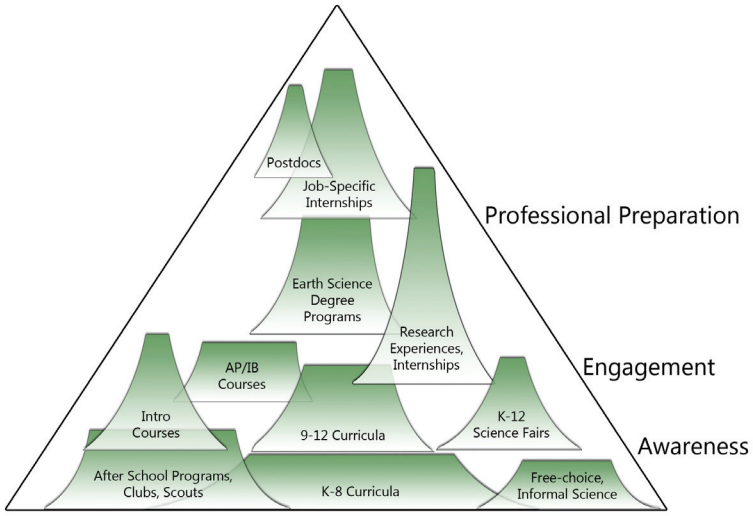

Figure 2a. Conceptual framework illustrating the types of programs and experiences that help move individuals along a pathway from awareness of earth science (base of triangle) toward an earth science career (apex of triangle). The framework is portrayed as a triangle because more individuals will develop an interest in earth science than will become engaged in the field, and more will become engaged in the field than will prepare for and pursue a career.

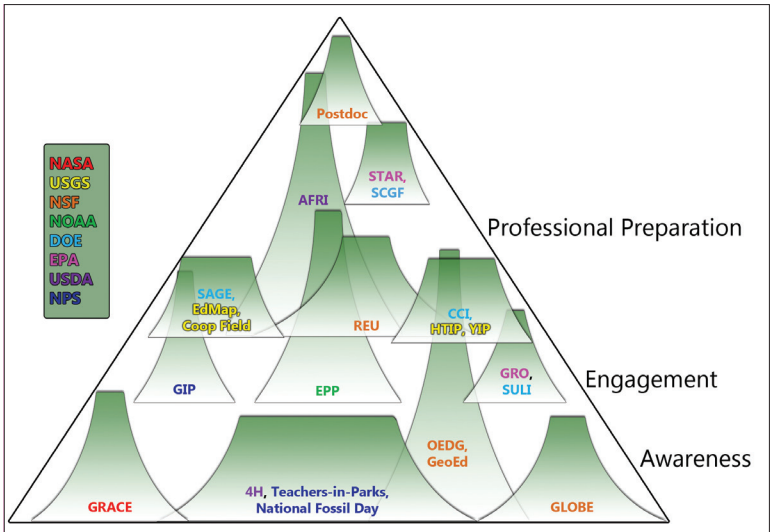

Figure 2b. Federal earth science education and training programs considered in this report from Box 1 placed within the committee's conceptual framework. Due to space constraints, programs that have a small earth science component or that were one-time competitions are not shown.

offered by other organizations into a system would help meet both goals.

Stronger and more visible connections between federal, academic, and professional society programs—for example, through a central listing of available internships—would increase the visibility of earth science education opportunities and help students find a path to an earth science career. Currently, the burden of finding opportunities in earth science rests heavily on students, who have only limited knowledge and experiences to draw on, and on their advisors, who are most aware of opportunities in their own specialties. As a result, some talented students may not be retained in the field.

A systems approach would also help federal agencies leverage resources. For example, by mapping their diversity programs onto a conceptual framework, such as the one illustrated in Figure 2a, agencies could identify potential partners and share effective practices for attracting and retaining minority students. Collaborations with professional societies focused on diversity, such as the National Association of Black Geoscientists, could help connect minority students to education and training opportunities and available positions. Coalitions of partners from federal agencies, private companies, universities, and professional societies would stretch federal dollars and bring a wide range of expertise to bear on the common goal of increasing diversity.

Evaluating Programs

In a time of reduced budgets, it is important for federal agencies to invest in education programs that are effective. Program evaluations provide a means and rationale for determining whether a program is succeeding and why. Such evaluations focus on understanding program goals, establishing criteria for success, and gathering data on program performance. Some programs considered in this report have demonstrated success through formal evaluations. Other programs may also be successful, but have not collected the data necessary to make this determination or to understand how to improve, sustain, or expand the effort. In addition, some stated program goals, such as improving understanding of earth science, are too broad to measure and evaluation criteria do not always match stated goals.

The lack of suitable data for identifying successful programs underscores the importance

of incorporating evaluation into program design. Logic models provide a useful mechanism for helping program managers define who the program is trying to reach, what it is trying to achieve, what resources it requires, and how to achieve near- and long-term results.

System-Level Evaluation

A system-level evaluation that encompasses all programs and activities within the framework of earth science opportunities could be used to identify imbalances in effort and gaps in support—information that could help agencies determine where future education and training efforts may be useful. Broad indicators of program activities could be developed by aggregating relevant information from individual program evaluations, and supplemented by targeted program evaluation aimed at understanding how to create effective programs. Network analysis of the programs in the system could reveal which connections among participating organizations help move individuals through the system, and qualitative studies would help show how individuals find education and training opportunities and what they learn from them.

Broadening the Participation of Underrepresented Groups

A key goal of federal government recruitment policies is to attain a workforce that draws from all segments of society and leverages diversity to deliver the best public service. However, the federal earth science workforce does not yet mirror the ethnic, racial, and gender diversity of the U.S. population.

Women have made substantial gains in earth science over the past several decades and now obtain 39 percent of bachelor's degrees in the field. In comparison, however, available literature shows that, with attention to biases and improved mentoring, it may be possible to narrow or eliminate the degree gap between women and men.

Compared to women, the gains of minorities in earth science education have been modest. Underrepresented minorities (African American, American Indian, and Hispanic or Latino of any race) comprised 30 percent of the U.S. population according to the 2010 census, but received only 7.2 percent of the earth science bachelor's degrees awarded in 2009.

Studies suggest that education and training programs that succeed in attracting and retaining minority students have some common elements, including building strong connections with communities and creating linkages with other programs to form clear educational pathways. The latter underscores the importance of thinking about education and training programs in the context of a system that moves students from awareness to preparation for an earth science career.

For more information, visit http://dels.nas.edu/besr or call (202) 334-2744.
Download free PDF or purchase the published report at http:/www.nap.edu or call (800) 624-6242 for bulk purchases.

Committee on Trends and Opportunities in Federal Earth Science Education and Workforce Development: Arthur Goldstein (*Chair*), Bridgewater State University, Massachusetts; **Pranoti Asher**, American Geophysical Union, Washington, D.C.; **Susan E. Cozzens**, Georgia Institute of Technology, Atlanta; **Cathryn A. Manduca**, Carleton College, Northfield, Minnesota; **Eric J. Pyle**, James Madison University, Harrisonburg, Virginia; **Eric M. Riggs**, Texas A&M University, College Station; **Karl Turekian**, emeritus, Yale University, New Haven, Connecticut (*deceased March 2013*); **Lisa D. White**, University of California Museum of Paleontology, Berkeley; **Anne M. Linn** (*Study Director, Board on Earth Sciences and Resources),* **Deborah Glickson** (*Senior Program Officer, Ocean Studies Board*), **Eric J. Edkin**, (*Senior Program Assistant, Board on Earth Sciences and Resources*), National Research Council.

The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Geological Survey. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

EXPERT CONSENSUS REPORT